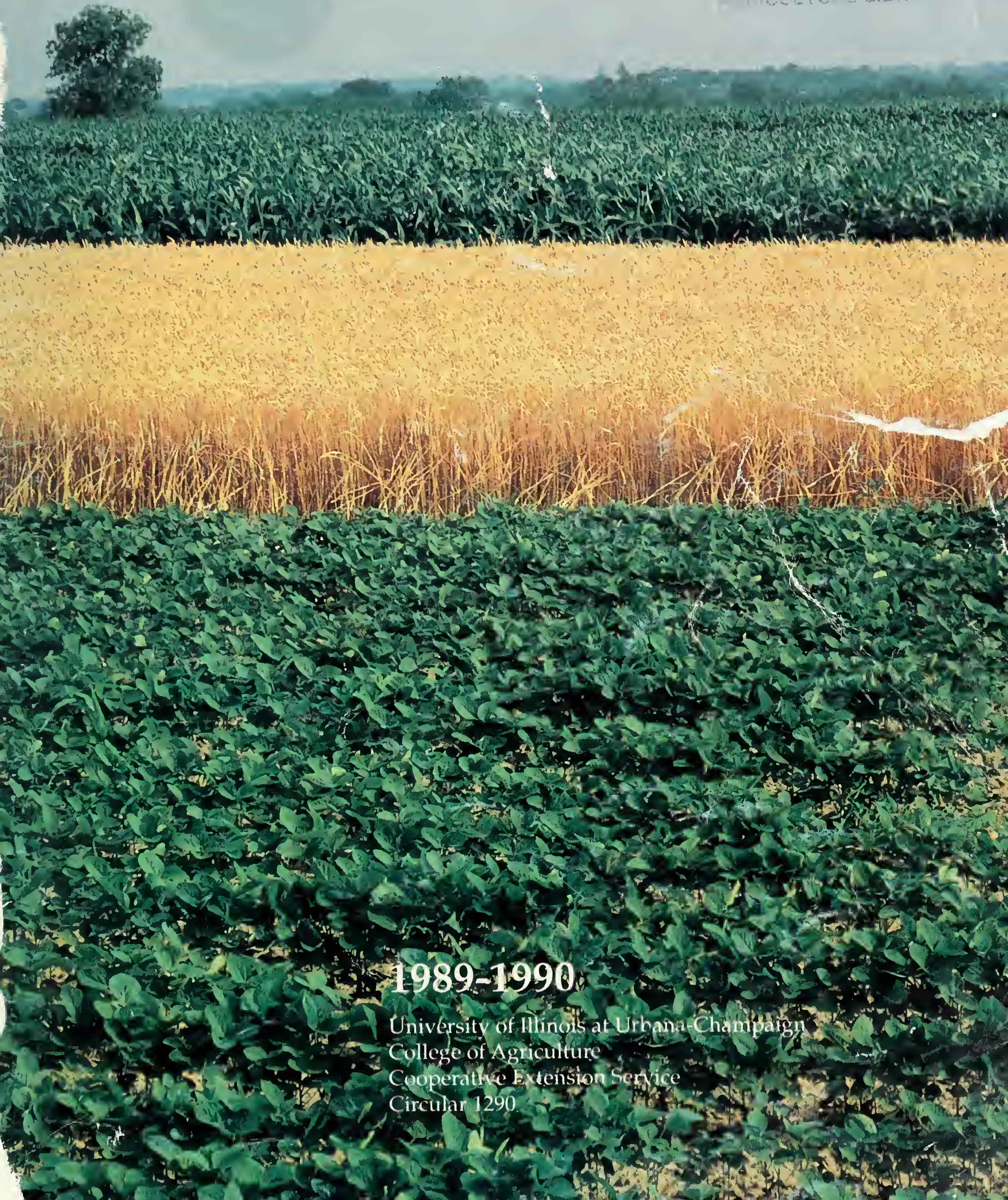
Illinois Agronomy Handbook



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Corn

Yield goals

Management decisions are made more easily if the corn producer has set realistic yield goals based on the soil, climate, and available equipment. Usually it is not realistic, for example, to set yield goals of 180 bushels per acre for a soil rated to produce only 100 bushels per acre and from which the highest yield ever produced was 130 bushels per acre. Instead, managing to achieve a realistic yield goal should result in yields greater than the goal in years when conditions are better than average and reduced losses when the weather is unfavorable. The yield goal should be considered an *average*; it will not guarantee high yields when the weather is poor.

The first step in establishing a yield goal is a thorough examination of the soil type. Information for each soil type, such as the productivity ratings given in *Soils of Illinois* (Bulletin 778), can be a useful guideline. This information, however, should be supplemented by 3- to 5-year yield records, county average yields, and the yields on neighboring farms. An attempt should be made to ignore short-term weather and to set a goal based on long-term temperature and rainfall patterns.

Hybrid selection

When tested under uniform conditions, the range in yield of available hybrids is often 30 to 50 bushels per acre. This variation in yield means that some of the most productive time the farmer spends may be in choosing which hybrid to plant. Maturity, yield for that maturity, standability, and disease resistance are the most important factors to consider when making this choice.

Concern exists with what many consider to be a lack of genetic diversity among commercially available hybrids. Although it is true that a limited number of genetic pools, or populations, were used to produce today's hybrids, it is important to realize that these pools contain a tremendous amount of genetic diversity. Even after many years of breeding, there is no evidence that this diversity has been fully exploited. In fact, a number of studies have shown that breeding progress is not slowed even after a large number of cycles of selection. Continued improvements in most desirable traits are evidence that this is true. Many of today's hybrids are substantially better than those that are only a few years old. For this reason, some producers feel that a hybrid "plays out" within a few years. Actually, the performance of a given hybrid remains constant over the years; but comparison with newer and better hybrids may make it appear to have declined in yielding ability.

Despite considerable genetic diversity, it is still possible to buy the same hybrid from several different companies. This happens when different companies buy inbreds from a foundation seed company that has a successful breeding program, or when hybrid seed is purchased on the wholesale market, then resold under a company label. In either case, hybrids are being sold on a nonexclusive basis, and companies simply put their own name and number on the bags.

Many producers, however, would like to avoid planting all of their acres to the same hybrid. One way is to buy from only one company, though this may not be the best strategy if it discourages looking at the whole range of available hybrids. Another way of assuring genetic diversity is to use hybrids with several different maturities. Finally, many dealers have at least some idea of what hybrids are very similar or identical and can provide such information if asked.

It is also important to remember that genetics are only part of the performance potential of any hybrid.

The care with which hybrid seed is produced — detasseling, harvesting, drying, grading, testing, and handling — can and does have a substantial effect on its performance. Be certain that the seed you are buying was produced in a professional manner.

Maturity is one of the important characteristics used in choosing a hybrid. Hybrids that use most of the growing season to mature generally produce higher yields than those that mature more quickly. The latest-maturing hybrid should reach maturity at least 2 weeks before the average date of the first killing freeze (32°F), which occurs about October 8 in northern Illinois, October 18 in central Illinois, and October 25 in southern Illinois. Physiological maturity is reached when kernel moisture is 30 to 35 percent and is easily identified by the appearance of a black layer on the base of the kernel where it attaches to the cob. The approach to maturity also can be monitored by checking the "milk line," which moves from the crown to the base of the kernel as starch is deposited. The kernel is mature about the time this milk line disappears at the base of the kernel.

Although full-season hybrids generally produce the highest yields, most producers choose hybrids of several different maturities. This practice allows harvest to start earlier and also reduces the risk of stress damage by lengthening the pollination period.

Comparing hybrid maturities may be difficult because there is no uniform way of describing this characteristic. Some companies use days to maturity, while others use growing degree days (GDD). Growing degree days is becoming more widely used, and it is usually possible to obtain this measure for any hybrid, either directly or by comparing maturity with a hybrid for which GDD is known.

The following formula can be used to calculate GDD accumulated on any given day:

$$GDD = \frac{H + L}{2} - 50°F$$

where H is the high temperature for the day (but no higher than 86°F) and L is the low temperature (but no lower than 50°F). For example (see the following table), if the daily high temperature were 95°F, calculate at 86°F, the cutoff point for high temperatures. If the daily low temperature were 40°F, calculate at 50°F, the cutoff point for low temperatures. These high and low cutoff temperatures are used because growth rates do not increase above 86°F and they do not decrease below 50°F.

The following figures are examples of daily high and low temperatures and the resulting GDD, calculated using the GDD formula:

Daily temperature High	Low	GDD
80	60	20
60	40	5
95	70	28
50	35	0

It is useful to keep a running total of daily GDD because GDD has been found useful in predicting the rate of development of the corn plant. For a full-season hybrid grown in central Illinois, the following table gives the approximate GDD required to reach certain growth stages:

Stage	GDD
Emergence	120
Two-leaf	200
Six-leaf (tassel initiation)	475
Ten-leaf	740
Fourteen-leaf	1,000
Tassel emergence	1,150
Silking	1,400
Dough stage	1,925
Dented	2,450
Physiological maturity (black layer)	2,700

These GDD numbers will vary with hybrid maturity. The relative proportion of full-season GDD required to reach each growth stage will, however, remain relatively constant. For example, GDD to silking will generally be about one-half of the GDD to physiological maturity.

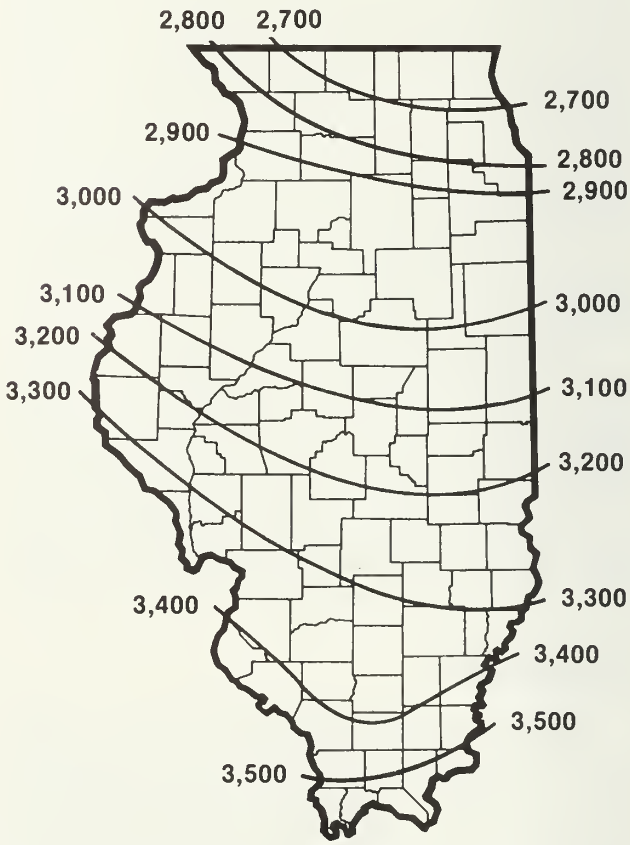


Figure 1. Average number of growing degree-days, May 1 through September 30, based on temperature data provided by the U.S. Department of Commerce, National Weather Service, 1951-1980.

A full-season hybrid for a particular area will generally mature in several hundred fewer GDD than that given in Figure 1. Thus, a full-season hybrid for northern Illinois would be one that matures in about 2,500 GDD, while for southern Illinois a hybrid that matures in 2,900 to 3,000 GDD would be considered full season. This GDD "cushion" reduces the risk of frost damage and also allows some flexibility in planting time; it may not be necessary to replace a full-season hybrid with one maturing in fewer GDD unless planting is delayed until late May.

After yield and maturity, resistance to lodging is probably the next most important factor in choosing a hybrid. Because large ears tend to draw nutrients from the stalk, some of the highest-yielding hybrids also have a tendency to lodge. Such hybrids may be profitable because of their high yields, but they should be closely watched as they reach maturity. If lodging begins, or if stalks become soft and weak (as determined by pinching or pushing on stalks), then harvesting these fields should begin early.

Resistance to diseases and insects are important characteristics in a corn hybrid. Leaf diseases are easiest to spot, but stalks also should be checked for diseases. Resistance to insects such as the European corn borer also is being incorporated into modern hybrids. Another useful trait is the ability of the hybrid to emerge under cool soil conditions, a trait that is especially important in reduced or zero-till planting.

With the large number of hybrids being sold, it is difficult to choose the best one. An important source of information on hybrid performance is the Illinois Cooperative Extension circular *Performance of Commercial Corn Hybrids in Illinois.* This summary reports hybrid tests run each year in ten locations and includes information from the previous 2 years. The circular gives data on yields, kernel moisture, and lodging of hybrids. Other sources of information include your own tests and tests conducted by seed companies, neighbors, and county Extension personnel.

You should see the results of as many tests as possible before choosing a hybrid. Good performance for more than one year is one important criterion. You should not base your decision on the results of only one "strip test." These tests use only one strip of each hybrid; the difference between two hybrids may therefore be due to location in the field rather than to an actual superiority of one over the other.

Planting date

Long-term studies show that the best time to plant corn in Illinois is around May 1, with little or no yield loss when planting is within a week on either side of this date. Weather and soil conditions permitting, you should begin planting sometime before this date to allow for bad working days (Table 1). Corn that is planted 10 days or 2 weeks before the optimum date may not yield quite as much as that planted on or near the optimum date, but it will usually yield considerably more than that planted 2 weeks or more after the optimum date (Table 2).

Table 1. Days Available and Percent of Calendar Days Available for Field Operations in Illinois[a]

Period	Northern Illinois		Central Illinois		Southern Illinois	
	Days	%	Days	%	Days	%
April 1-20[b]	5.8	(29)	4.2	(21)	2.6	(13)
April 21-30[c]	3.5	(35)	3.1	(31)	2.6	(26)
May 1-10[c]	5.8	(58)	4.3	(43)	3.5	(35)
May 11-20[c]	5.5	(55)	5.0	(50)	4.4	(44)
May 21-30[c]	7.4	(74)	5.8	(58)	5.4	(54)
May 31-June 9[c]	6.0	(60)	5.4	(54)	5.6	(56)
June 10-19[c]	6.0	(60)	5.4	(54)	5.8	(58)

[a] Summary prepared by R.A. Hinton, Department of Agricultural Economics of the University of Illinois Cooperative Crop Reporting Service, unpublished official estimates of Favorable Work Days, 1955-1975. The summary is the mean of favorable days omitting Sundays, less one standard error, representing the days available 5 years out of 6.
[b] 20 days
[c] 10 days

Table 2. Effect of Planting Date on Yield[a]

	Northern Illinois	Central Illinois	Southern Illinois
	bushels per acre		
Late April	...	156	102
Early May	151	162	105
Mid-May	150	...	82
Early June	100	133	58

[a] 3-year average at each location

In general, yields will decline slowly as planting is delayed up to May 10. From May 10 to May 20, the yield will decline about one-half bushel for each day that planting is delayed. This loss will increase to 1 to 1½ bushels per day from May 20 to June 1, with greater reductions in northern Illinois than in the southern part of the state. After June 1, yields decline very sharply with delays in planting. The latest practical date to plant corn ranges from about June 15 in northern to July 1 in southern Illinois. If you plant this late, expect only 50 percent of the normal yield.

Early planting results in drier corn in the fall, allows for more control over the planting date, and allows for a greater choice of maturity in hybrids. In addition, if the first crop is damaged, the decision to replant can often be made early enough to allow you to use your first-choice hybrid. Of course, early planting has some disadvantages: (1) the cold, wet soil may produce a poor stand; (2) weed control may be more difficult; and (3) plants may suffer from frost. Improved seed treatments and herbicides, however, have greatly reduced the first two hazards; and the fact that the growing point of the corn plant remains below the soil surface for 2 to 3 weeks after emergence minimizes the third hazard. Because it is below the surface, this part of the plant is seldom damaged by cold weather unless the soil freezes. Even when corn is frosted,

therefore, the probability of regrowth is excellent. For these reasons, the advantages of early planting are felt to outweigh the disadvantages.

The lowest temperature at which corn will germinate is about 50°F; therefore, planting may begin when the soil temperature at planting depth is at least 50°F. The 5-day weather forecast also should be favorable. You probably will need to determine the soil temperature on your own because soil temperatures reported by weather bureaus usually are taken under sod. The midday temperature at 2 to 4 inches under sod often is 8 to 12 degrees lower than it is under bare ground.

The following guidelines may be helpful:

1. Plant when the temperature at 7 a.m. reaches 50°F at the 2-inch level. This will assure a favorable temperature for growth during most of a 24-hour period if there is an appreciable amount of sunshine.
2. Plant when the temperature at 1 p.m. reaches 55°F at the 4-inch level. The 4-inch level is suggested for the 1 p.m. measurement because this level is not affected as much as the 2-inch level by a single day of bright sunshine.

After April 25, plant if the soil is dry enough, even if the soil temperature is below the suggested guidelines. As a rule of thumb, plant according to soil temperature early in the season; and later, plant by the calendar.

Some areas, such as river bottoms and low-lying flatlands, tend to warm up slowly and are subject to late freezes. These areas should be planted last.

When planting in April, plant the full-season hybrids first and be sure of your weed control program. You may also consider increasing your planting rate, by 1,000 to 2,000 kernels per acre, because the early-planted corn is normally shorter and is less likely to be under moisture stress when pollinating.

Planting depth

Ideal planting depth varies with soil and weather conditions. Emergence will be more rapid from relatively shallow-planted corn; therefore, early planting should not be as deep as later planting. For normal conditions, an ideal depth is about 2 inches. Early-planted corn should not be any deeper than that; as much as one-half inch shallower is preferred. Later in the season, when temperatures are higher and evaporation is greater, planting as much as 3 inches deep to reach moist soil may be advantageous.

Depth-of-planting studies show that not only do fewer plants emerge when planted deep but also that those emerging often take longer to reach the pollinating stage and may have higher moisture in the fall.

Plant population

Your goal at planting time is the highest population per acre that can be supported with normal rainfall without excessive lodging, barren plants, or pollination problems. But how do you know when you have found the ideal or optimum population for a particular field? Check the field for average ear weight. You can check at maturity or estimate by counting kernels (number of rows multiplied by number of kernels per row) once the kernel number is set. Most studies in Illinois suggest that the optimum plant population will produce ears weighing about one-half pound or having about 640 kernels. A half-pound ear should shell out 0.4 pound of grain at 15.5-percent moisture.

In the study reported in Table 3, ear size reached one-half pound when the plant population was slightly less than 25,000 per acre. At higher populations, the increase in the number of plants was nearly matched by the reduction in ear size.

The optimum population for a particular field is influenced by several factors, some of which you can control and some over which you have little or no control. Concentrate on those factors that you can control. For instance, you can do little to affect the amount of water available to the crop during the growing season. This variable is determined by the soil type and the total amount and distribution of the rainfall between the time the crop is planted and when it is mature. You can, however, do much to determine how efficiently this water is used. The more efficient its use, the higher the population that can be supported with the water that is available. Remember that ear number is generally more important than ear size, and that the most practical way to increase ear number with today's hybrids is through population control.

Two very important controllable factors influencing the efficiency of water use are soil fertility and weeds. Keep the fertility level of your soil high and the weed population low.

Other factors that are important include:

1. **Hybrid selection.** Hybrids differ in their tolerance to the stress of high populations. Most modern hybrids can, however, tolerate populations of 20,000 to 24,000 per acre on most Illinois soils. Some need even higher populations — 25,000 to 30,000 per acre — to produce the best yields.
2. **Planting date.** Early planting enables the plant to produce more of its vegetative growth during the long days of summer and to finish pollinating before the hot, dry weather that is normal for July and early August.

Table 3. Effect of Plant Population on Corn Yield

Plants per acre	Yield[a]
	bushels per acre
15,000	140
20,000	163
25,000	175
30,000	179
35,000	179

[a] Average of 8 trials (with 2-4 hybrids each) conducted at Urbana, Monmouth, and DeKalb over a 3-year period

3. **Row spacing.** The more uniform distribution of plants grown in narrow rows improves the efficiency of water use.
4. **Insect and disease control.**

The harvest population is always less than the number of seeds planted. Insects, diseases, adverse soil conditions, and other hazards take their toll. You can expect from 10 to 20 percent fewer plants at harvest than seeds planted (Table 4).

Row spacing

Because of the clear yield advantage from using a row spacing of less than 40 inches (Table 5), many producers have reduced row spacing; some 40 percent of the corn acres in Illinois are planted in 30-inch rows, and the average row spacing in the state is about 35 inches. A few producers in the Corn Belt use rows less than 30 inches apart. Although the yield increase going from 30- to 20-inch rows will normally be less than that gained by going from 40- to 30-inch spacing, most studies have shown yield increases of about 5 percent when rows are narrowed from 30 to 20 inches. Equipment for harvesting 20-inch rows is not readily available at present.

Replanting

Although it is normal that 10 to 15 percent of planted seeds fail to establish healthy plants, additional stand losses due to insects, frost, hail, flooding, or poor seedbed conditions may call for a decision on whether or not to replant a field. The first rule in such a case is not to make a hasty decision. Corn plants can and often will outgrow leaf damage, especially when the growing point, or tip of the stem, is protected beneath the soil surface or up until about the six-leaf stage. If new leaf growth appears within a few days after the injury, then the plant is likely to survive and produce normal yields.

When deciding whether to replant a field, you will need the following information: (1) original planting date and plant stand, (2) possible replanting date and plant stand, and (3) cost of seed and pest control for replanting.

Table 4. Planting Rate That Allows for a 15-Percent Loss from Planting to Harvest

Plants per acre at harvest	Seeds per acre at planting time
16,000	18,800
18,000	21,200
20,000	23,500
22,000	25,900
24,000	28,200
26,000	30,600
28,000	33,000
30,000	35,300

If you did not count the plant stand before damage occurred, population can be estimated by reducing the dropped seed rate by 10 percent, providing that conditions for emergence were normal. To estimate stand after injury, count the number of living plants in $\frac{1}{1,000}$ of an acre (Table 6). Take as many counts as needed to get a good average, one count for every 2 to 3 acres.

When the necessary information on stands and planting and replanting dates has been assembled, use Table 7 to determine both the loss in yield to be expected from the stand reduction and the yield you can expect if you replant the field.

To use Table 7, locate the expected yield of the reduced plant stand by reading across from the original planting date to the plant stand after injury. Then locate the expected replant yield by reading across from the expected replanting date to the stand you would replant to. The difference between these numbers is the expected percentage yield increase (or decrease) to be expected from replanting. For example, corn that was planted on April 25, but with a plant stand reduced to 18,000 by cutworm injury, would be expected to yield 90 percent of a normal stand. If such a field were replanted on May 16 to establish 25,000 plants per acre, the expected yield would be 98 percent

Table 5. Effect of Row Width on Corn Yield, Urbana

Plants per acre	Row width: 40 inches	Row width: 30 inches
	bushels per acre	
16,000	127	132
24,000	133	144
32,000	126	138

Table 6. Row Length Required To Equal 1/1,000 Acre

Row width	Row length
20″	26′1″
28″	18′8″
30″	17′5″
32″	16′4″
36″	14′6″
38″	13′9″
40″	13′1″

Table 7. Yield of Uniformly Spaced Corn Plants with Different Planting Dates and Plant Populations

Planting date	Plants per acre at harvest: 14,000	16,000	18,000	20,000	22,500	25,000
	percent of maximum yield					
April 25	81	86	90	93	96	98
May 6	83	88	92	95	98	100
May 16	81	86	90	93	96	98
May 26	75	80	84	87	90	92
June 10	58	63	67	70	73	75

of normal. Whether or not it will pay to replant such a field will depend on whether the yield increase of eight percentage points would repay the replanting costs. In this example, if replanting is delayed until near the end of May, the yield increase to be gained from replanting disappears.

Although uniformity of stand cannot be measured easily, studies have indicated that reduced plant stands will yield better if plants are spaced uniformly than if there are large gaps in the row. As a general guideline, yields will be reduced an additional 5 percent if there are many gaps of 4 to 6 feet in the row and an additional 2 percent for gaps of 1 to 3 feet.

Estimating yields

Making plans for storage and marketing of the corn crop often calls for estimating yields before the crop is harvested. Such estimations are easier to make for corn than for most other crops because we can count fairly accurately the number of plants or ears per acre.

Estimating corn yields is done by counting the number of ears per acre and the number of kernels per ear, then multiplying these two numbers to get an estimate of the number of kernels per acre. Next, simply divide by an average number of kernels in a normal bushel to get the yield in bushels per acre.

Corn yields can be estimated after the kernel number is fixed — about 2 weeks after the end of pollination. The following steps are suggested:

1. Walk out in the field a predetermined number of rows and paces: For example, go 25 rows from the edge of the field and 85 paces from the end of the field. If this pattern is not determined beforehand, there will be a tendency to stop where the crop looks better than average. Stop *exactly* where planned.
2. Measure $\frac{1}{1,000}$ of an acre (Table 6), and count the number of *ears* (not stalks) in that distance. Do not count ears with only a few scattered kernels.
3. Take three ears from the row that was counted. To avoid taking only good ears, take the third, sixth, and tenth ears in the length of row. Do not take ears with so few kernels that they were not included in the ear count.
4. Count the number of rows of kernels and the number of kernels per row on each ear. Multiply these two numbers together for each ear, then average this kernel count for the three ears.
5. Calculate yield using the following formula:

$$\text{bu/acre} = \frac{\text{number of ears per } \frac{1}{1,000} \text{ acre} \times \text{average number of kernels per ear}}{90}$$

6. To get a reliable average, repeat this process at least once for every 5 acres in a field.

In the formula given, the number 90 is used based on the assumption that a bushel of normal-sized seed contains about 90,000 kernels. The zeros are dropped because the plant population is given in thousands per acre.

Specialty types of corn

Erratic and generally low world corn prices have resulted in considerable interest among producers in growing various specialty types of corn, either for export or for domestic use. This may mean higher profits if the supply of such types is quite small. Because the total demand might also be quite limited, however, the price advantage may disappear as more producers start growing a particular specialty type. It is therefore important to have alternative (nonspecialty) uses for the crop, and to grow types that do not yield substantially less than normal corn, in the event that the corn cannot be sold for its intended special use.

Many specialty types are grown under contract. The contract buyers often specify what hybrids may or may not be used, and they may specify other production practices to be used. Some contracts also may include pricing information and quality specifications.

Risks associated with growing specialty types of corn vary considerably. Milling companies may buy corn with "food-grade endosperm," requiring only that the grower choose hybrids from a relatively long list of popularly grown hybrids; the risk in this case is small. On the other hand, inbreds used to produce some hybrids are not very vigorous, and seed corn production with such inbreds might be very risky. Production contracts in such cases may shift some of the risk to the buyer. In any case, every grower of specialty types of corn should be aware of risks associated with each type.

White corn. Most of the white corn grown in the United States is used to make corn flakes and cornmeal. It often sells at a higher price than yellow corn, sometimes as much as one-half to two times the price of yellow corn.

The cultural practices for producing white corn are the same as those for yellow corn except that relatively few white hybrids are available in maturities adapted to Illinois. Choice of hybrid is therefore important. In addition, kernels fertilized by pollen from yellow hybrids will be light yellow. These yellowish kernels are undesirable. The official standards for corn specify that white corn cannot contain more than 2 percent of corn of other colors; therefore, white corn probably should not be planted on land that produced yellow corn the year before. It may also be desirable to harvest the outside ten or twelve rows separately from the rest of the field. Most of the pollen from adjacent yellow corn will be trapped in those outer rows.

High-lysine corn. Lysine is one of the amino acids essential to animal life. Livestock producers need not

be concerned whether or not the protein that ruminant animals eat contains this amino acid because the microflora in rumen can synthesize lysine from lysine-deficient protein. Nonruminants cannot do this, however, so swine, poultry, and humans must have a source of protein that contains sufficient lysine to meet their needs.

Normal dent corn is deficient in lysine. The discovery in 1964 that the level of this essential amino acid is controlled genetically and can be increased by incorporating a gene called Opaque 2 was exciting news to both the corn geneticist and the animal nutritionist. The potential value of this discovery to the swine farmer was obvious when feeding trials demonstrated that substantially less soybean meal was required when high-lysine corn was fed to swine.

Agronomic research with high-lysine corn indicates that it is slightly lower in yield and higher in moisture than its normal counterpart. Furthermore, the kernel is softer and more susceptible to damage. Current research with more sophisticated hybrids, however, has successfully reduced some of these differences.

The Opaque 2 gene is recessive: High-lysine corn pollinated by normal pollen produces normal low-lysine grain. Although isolation from normal corn is not essential, regular hybrids, for example, should not be strip planted in high-lysine corn nor should high-lysine corn be planted where the number of volunteer corn plants will be high.

Popcorn. As with several of the other specialty types of corn, most of the popcorn produced in Illinois is under contract to processors. While there are several dozen hybrids from which to choose, the processor may require that a hybrid be grown for its particular kernel characteristics rather than for yield alone. Thus, income per acre should be considered because low-yielding hybrids may often bring a higher price.

Cultural practices for popcorn are much like those for field corn. Popcorn often is attacked by stalk rot; therefore, excessively high plant populations should be avoided, and harvest should begin as soon as the grain is dry enough. Weed control also may be more difficult because of slower emergence and early growth. Rotary hoeing and cultivation may be useful supplements to chemical weed control. Because popcorn yields 30 to 40 percent less than field corn, fertilizer needs should generally be somewhat lower.

Many newer popcorn hybrids are "dent sterile," meaning that field-corn pollen cannot fertilize popcorn kernels. This trait should reduce the need for isolation, but be sure to check with the contractor to verify this. Generally, it is best to avoid planting popcorn in a field where field corn grew the previous season.

High-oil corn. In the summer of 1896, C.G. Hopkins of the University of Illinois started breeding corn for high oil content. With the exception of 3 years during World War II, this research has continued. The oil content of the material that has been under continuous selection has been increased to 17.5 percent from the 4 to 5 percent that is normal for dent corn.

Until recently, yields were disappointing for varieties with higher oil content than normal dent corn. Recent research involving new gene pools of high-oil material unrelated to the original Illinois High Oil indicates that varieties containing 7- to 8-percent oil may be produced with little or no sacrifice in yield. Higher-oil hybrids are now being marketed on a limited scale.

Because oil is higher in energy per pound than starch is, a livestock ration containing high-oil corn should have some advantage over one containing normal corn. Feeding trials involving high-oil corn have generally confirmed this assumption. Interest by the corn-milling industry in high-oil corn as a source of edible oil is increasing. Corn oil has a high ratio of polyunsaturated fatty acids to saturated fatty acids; it is used in salad oils, margarine, and cooking oils.

Waxy maize. Waxy maize is a type of corn that contains 100-percent amylopectin starch instead of the 75 percent typical for ordinary dent hybrids. Amylopectin starch is used in many food and industrial products. Several corn-milling companies annually contract for its production in the central Corn Belt.

The waxy characteristic is controlled by a recessive gene, which means that waxy corn pollinated by pollen from normal corn will develop into normal dent corn. Waxy corn, like high-lysine corn, should not be planted in fields where dent corn is likely to volunteer. The outside six to ten rows may also need to be segregated from the rest of the field to keep the amount of contamination from normal corn at an acceptable level.

High-amylose corn. In high-amylose corn, the amylose starch content has been increased to more than 50 percent. Normal corn contains 25-percent amylose starch and 75-percent amylopectin starch.

The amylose starch content also is controlled by a recessive gene; therefore, isolation of production fields is important, as is selecting production fields that were not planted in normal corn the previous year.

Soybeans

Planting date

Soybeans generally yield best when planted in May, with full-season varieties tending to yield best when planted in early May. Earlier varieties, however, often yield more when planted in late May than in early May. When the planting of full-season varieties is delayed until late May, the loss in yield is minor compared with the penalty for planting corn late. Therefore, the practice of planting soybeans after corn has been planted is accepted and wise.

The loss in yield of soybeans becomes more severe when planting is delayed past early June. The penalty, however, for late-planted corn is proportionally greater, and the danger of wet or soft corn becomes such a threat that soybeans are, under most conditions, a better crop for late planting than corn. Table 8 illustrates yield losses resulting from delayed planting of soybeans.

Planting date has an effect upon the length of time it takes soybeans to mature. The vegetative stage (planting to the beginning of flowering) is 45 to 60 days for full-season varieties planted at the normal time. This period is shortened as planting is delayed and may be only about 25 days when these varieties are planted in late June or early July.

Soybeans are photoperiod responsive and the length of the night or dark period is the main factor that determines when flowering begins. Also, the vegetative period is influenced by temperatures — with high temperatures shortening and low temperatures lengthening it. But the main effect remains that of the length of the dark period.

As planting is delayed, the length of the flowering period and that of pod filling also are shortened; but the effect of planting time on these periods is minor compared with that on the vegetative period.

As the length of the vegetative period grows shorter, because of delayed planting, soybean plants mature in fewer days (Table 9).

Planting rate

Maximum yields for May and very early June plantings of soybeans generally are provided by planting rates that result in 8 to 10 plants per foot of row at harvest in 40-inch rows, 6 to 8 plants in 30-inch rows, 4 to 6 plants in 20-inch rows, or 3 to 4 plants in 10-inch rows. Higher populations will usually result in excessive lodging in all varieties except those that are extremely lodging resistant. With populations that are sufficiently low, yield may be lower because the plants fail to form a complete canopy, which fully utilizes available sunlight. Lower population densities also tend to branch more and pod lower, two factors that can lead to increased harvest losses and lower yields.

As row spacing narrows, fewer seeds per foot of row are needed to achieve a given rate of seeds per acre (Table 10). Remember that the plant population achieved is always less than the seeding rate used. Some seeds simply are not viable, while others fail to establish a plant because of disease, excessive planting depth, or other problems.

Seeding-rate studies have demonstrated the productive capacity of soybeans at rather low plant densities. At extremely low plant densities, a considerable amount of the production may not be harvestable with a conventional combine because of low podding and excessive branching on the plant. Precipitation during vegetative development will help determine what the "ideal" plant density is for a given year. In a dry year, when vegetative development of plants is restricted, thicker stands of soybeans are desirable so that the

Table 8. Effect of Planting Date on Soybean Yields

Variety	Date of planting			
	May 7	May 21	June 8	June 19
	bushels per acre			
Urbana location				
Corsoy	56	62	49	42
Beeson	57	55	52	47
Calland	56	51	47	40
	May 3	May 17	June 7	July 1
Carbondale location				
Corsoy	27	38	43	28
Cutler	62	46	54	27
Dare	72	45	37	32

Table 9. Effect of Planting Date on Days to Maturity, Soybeans

Variety	Date of planting			
		May 1	June 1	June 12
	days to maturity			
Columbia, Missouri (6-year average)				
Hawkeye		122	104	98
Clark		149	115	105
	May 3	May 17	June 7	July 1
Carbondale location				
Corsoy	118	103	107	101
Wayne	131	117	117	105
Cutler	145	133	117	108
Dare	159	153	138	122

Table 10. Number of Seeds Required To Achieve Given Seeding Rates in Various Row Widths

Desired seed rate/acre	Row width, inches					
	36	30	20	15	10	7
	seeds required per row-foot					
100,000	6.9	5.7	3.8	2.9	1.9	1.3
125,000	8.6	7.1	4.7	3.6	2.4	1.6
150,000	10.3	8.6	5.7	4.3	2.9	2.0
175,000	12.1	10.0	6.7	5.0	3.3	2.3
200,000	13.8	11.4	7.6	5.8	3.8	2.6

smaller plants can develop a full crop canopy. In a year with considerable rain during May and June, which causes plants to grow taller and can lead to lodging by the crop, somewhat lower plant densities are better to avoid excessive lodging. At the time of planting, however, you cannot predict precipitation during vegetative growth, so a compromise in seeding rate offers the most potential.

Seeding-rate trials conducted on numerous varieties across several years suggest that a wide range of seeding rates will produce good yields. Seeding rates of 110,000 to 150,000 seeds per acre tend to produce the best yields (Figure 2). For seed of average size, these rates correspond to roughly 40 to 60 pounds per acre. Planting at rates toward the high end of this range helps ensure a full stand, while planting toward the low end of the range helps conserve seed. Virtually all soybean varieties respond to changes in seeding rate in a similar manner. Possible exceptions are varieties with weak stems (which lodge easily) and those with a determinate growth habit (which have reduced capacity to produce vegetative growth after the onset of flowering).

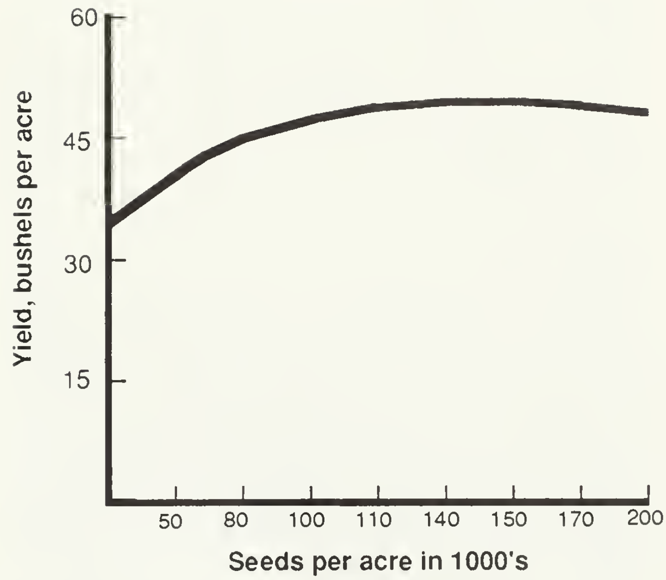


Figure 2. Effect of seeding rate on soybean yields.

If seeding of soybeans is delayed until late June or early July, vegetative development of the plant will be greatly reduced. The smaller plants that develop will be resistant to lodging. The small stature of the plants limits the amount of sunlight each can intercept; to compensate for this effect, the seeding rate is increased. Increases of 50 to 100 percent over that suggested for May plantings are advisable.

Planting depth

Emergence will be more rapid and stands will be more uniform if soybeans are planted only 1½ to 2 inches deep. Deeper planting often results in lower emergence and poor stands.

Varieties differ in their ability to emerge when planted more than 2 inches deep. The description of a variety may mention an "emergence score," which reflects the ability of the seedling hypocotyl to elongate sufficiently when planting is deeper than recommended. Scores for emergence are usually given on a 1-to-5 scale, with a score of 1 indicating that the likelihood of emergence is very good and a score of 5 indicating that such probability is very weak. Special attention should be given to the planting depth of

varieties that are known to have weaker emergence potentials. Because a variety has a tendency to emerge slowly or weakly from excessively deep planting does not mean it lacks the ability to produce a good crop when planted at a reasonable depth. It simply means that extra attention to depth of planting is needed to ensure a good stand.

Crop rotation

The crop preceding soybeans has an influence on yield potential. If soybeans are planted after soybeans, diseases and other pest problems may be intensified in the second and later years of production. Difficult-to-control weed problems will become worse. In addition, research evidence suggests that growth-inhibiting substances (allelopathic chemicals) are released from soybean residue as it decomposes in the soil. These substances have a negative effect on growth and production of soybeans. To avoid this problem, sufficient time must elapse between one soybean crop and the next to allow decomposition of the soybean crop residue. Planting soybeans after soybeans will not provide a sufficient interval.

Several studies on the rotation benefits for soybean yield have been done. Table 11 summarizes these results, which indicate that higher yields tend to result from soybeans grown in rotation, compared to those from soybeans after soybeans.

Row width

If weeds are controlled, soybeans often will yield more in narrow rows than in traditional row spacings of at least 30 inches. The yield advantage for narrow rows is usually greatest for earlier-maturing varieties, with full-season varieties showing smaller gains in yield as row spacing is reduced to less than 30 inches. A multiyear study illustrates that average gains for narrow versus wider row spacings will vary from year to year (Table 12).

The following rule of thumb predicts situations in which narrower row spacings will likely be advantageous to yield: If a full canopy of leaves is not developed over the ground by the time that pod development begins, narrower spacings for soybeans can be advantageous to yield.

In addition to row spacing, factors that influence canopy development by the time podding begins are (1) relative maturity of the variety grown, (2) growing conditions during the vegetative period of plant development, and (3) planting date. Varieties that mature relatively early generally have the smallest canopies when podding begins and, consequently, can benefit most from narrow-row spacings. Dry or otherwise undesirable weather early in the season will reduce the amount of canopy developed before the onset of flowering by the soybean. When such weather patterns occur, rows that are more narrow help develop a full canopy by the time podding begins. Delays in planting reduce the amount of canopy that develops before seed formation activity of the plant begins; thus when planting is delayed considerably, soybeans respond to narrower rows with yield increases. Double-crop soybeans planted after the small-grain harvest should be planted in rows no wider than 20 inches (Table 13).

For many years, some Illinois farmers have planted their soybeans with a grain drill. Interest in this planting method has increased to the point that in 1988 about 20 percent of the soybean acres of Illinois were planted this way. The availability of improved herbicides has helped producers to expand the use of this planting method. If the weeds can be kept under control, the small-grain drill is a practical narrow-row planting device for soybeans. Research does not always show an advantage for the 7- or 8-inch rows over 15- or 20-inch spacings, but the drilled beans usually yield better than those planted in rows spaced at least 30 inches apart. A key factor to successful planting with a grain drill is good weed control. Also, with a grain drill, planting depth is more difficult to control. Because of these possible problems, farmers trying this planting method are wise to do so on a small acreage first.

For additional information about planting soybeans with a grain drill, see Illinois Cooperative Extension Service Circular 1161, *Narrow-Row Soybeans: What to Consider.*

Table 11. Effect of Crop Rotation on Soybean Yields

Location	Soybeans after Soybeans	Soybeans after Corn
	bushels per acre	
DeKalb	39	44
Dixon	30	35
Urbana	44	50
Brownstown	30	35

Table 12. Average Yield of 30 Soybean Lines in Wide- and Narrow-Row Spacings, 1980-83

Year	Row spacings, inches			Narrow-row yield advantage
	30	15	10	
1980	39.8	41.4	...	4%
1981	55.8	...	61.6	10%
1982	56.1	...	57.9	3%
1983	53.5	...	54.4	2%

Table 13. Yield of Double-Crop Soybeans When Planted in 20- and 30-Inch Rows, 1972

Site	Row spacings, inches	
	20	30
Dixon Springs	53	43
Brownstown	37	32
Urbana	33	24

When to replant

Uniform full stands have been compared to those with irregular deficiencies of varying magnitudes to evaluate yield potentials of stands that are less than perfect (Tables 14 and 15). Studies strongly suggest that the soybean plant has a tremendous ability to compensate for missing plants. By developing more branches and podding more heavily, the effect of missing plants in the stand is often not detected in yields. Yield reduction that is suffered with very poor stands may still be more profitable to the grower than a replanted field, which has additional costs associated with replanting and a reduced yield potential because of a delayed seeding date.

Data in Table 14 illustrate the soybean's ability to compensate for missing plants when randomly placed gaps occur in the stand. The influence of plant density in the remaining row sections is also apparent from the table. For soybeans to exhibit their full capacity to compensate for missing plants, it is necessary to control weed growth in the areas without soybean plants. In a field situation where poor stands are realized, management to control weeds is essential to prevent further yield losses due to the poor stand. The cost of maintaining the necessary weed control must be considered a cost of keeping a less-than-perfect stand.

Growers who replant do so at a later planting date than is the optimum. A penalty to yield due to delayed planting of 2 to 3 weeks is reflected in values presented in Table 15. The plant density per foot of row achieved with replanting, along with possible gaps in that stand, will also influence yield potential. It is wise to remember that replanted soybeans are not guaranteed to grow: A perfect stand is not always achieved when a poor stand is destroyed and the field replanted.

At a given level of stand reduction, the impact on yield is minimized if the gaps are small rather than large in size. A gap size of 16 inches has been found to have no influence on yield of soybeans grown in 30-inch row spacing, provided adjacent rows have a full stand. Compensation for gaps in the row has been found to occur not only in the row where the gap is located but also in the rows bordering the gap. The degree of compensation exhibited by soybeans should be enhanced as rows are spaced closer together, for under such planting arrangements the plants are initially more uniformly spaced in the field, making it more likely they can fully compensate for a stand deficiency of a given level. Extension Circular 1265, *Soybean Replanting Considerations for Maximizing Returns,* can be useful to growers making a replanting decision.

Table 14. Percent of Full-Yield Potential for Timely Planted Soybeans, as Influenced by Plants per Foot of Row and Percent Stand Reduction

Stand reduction	Plants per foot of row[a]		
	8	6	4
	percent of full-yield potential		
0 (full stand)	100	97	95
10 percent	98	96	93
20 percent	96	93	91
30 percent	93	90	88
40 percent	89	86	83
50 percent	84	81	78
60 percent	78	75	73

[a] Plants per foot of row in row sections with no gaps or skips.

Table 15. Percent of Full Yield Expected from Replanting Soybeans, as Influenced by Plants per Foot of Row and Stand Deficiency

Stand-deficiency level	Plants per foot of row[a]		
	8	6	4
	percent of full-yield potential		
0 (full stand)	89	86	83
10 percent	88	85	83
20 percent	86	84	81
30 percent	84	81	79
40 percent	81	78	75
50 percent	76	74	71
60 percent	71	69	66

[a] Plants per foot of row in row sections with no gaps or skips.

Double-cropping

See Illinois Cooperative Extension Circular 1106, *Double-Cropping in Illinois.*

Seed source

To ensure a good crop, you must do a good job of selecting seed. When evaluating seed quality, consider the percent germination, percent pure seed, percent inert matter, percent weed seed, and the presence of diseased and damaged seed.

Samples of soybean seed taken from the planter box as farmers were planting showed that homegrown seed was inferior to seed from other sources (Table 16). The number of seeds that germinate and the pure seed content of homegrown seeds were lower. Weed seed content, percent inert material (hulls, straw, dirt, and stones), and presence of other crop seeds (particularly corn) in homegrown seed were higher.

This evidence indicates that the Illinois farmer can improve soybean production potential by using higher-

Table 16. Quality Differences in Soybeans from Different Sources

Source	Germination, %	Pure seed, %	Inert matter, %	Seed cleaned, %	Seed germination tested, %
1985 survey					
Certified seed	88.2	99.5	0.42	100	100
Bin-run seed	85.9	98.1	1.19	51	14
1986 survey					
Certified seed	89.0	99.4	0.29	100	100
Bin-run seed	87.7	98.6	1.59	90	10

quality seed. Homegrown seed is the basic problem. Few producers are equipped to carefully harvest, dry, store, and clean seeds, and to perform laboratory tests that adequately assure high-quality seed. A grower who is not a professional seed producer and processor may be well advised to market the homegrown soybeans and obtain high-quality seed from a reputable professional dealer.

A state seed tag is attached to each legal sale from a seed dealer. Read the analysis and evaluate if the seed being purchased has the desired germination, purity of seed, and freedom from weeds, inert material, and other crop seeds. The certification tag verifies that an unbiased nonprofit organization (in our state, the Illinois Crop Improvement Association) has inspected the production field and the processing plant. These inspections make certain that the seeds are of a particular variety as named and have met certain minimum quality standards. Because some seed dealers may have higher quality seed than others, it always pays to read the tag.

Seed size

The issue of how the size of seed planted affects soybean growth and the final yield often arises following a year with stress during the seed-fill period, which reduces final seed size. Research suggests little detrimental effect from planting seed that is smaller than normal.

Across a broad range of seed sizes, insignificant effects on emergence have been reported. Seed of extremely small size, which normally do not make their way into the seed market, may be reduced in emergence when planted at a normal seeding depth of 1 to 2 inches. Interestingly, though, at excessive seeding depths (3 inches) the smaller seed have been reported to enjoy an advantage over large ones. This advantage may be caused by the smaller cross-sectional dimension of their cotyledons, which much be dragged up through the soil.

Final differences in plant size, which might result from planting seed of different sizes, do not suggest any problems with using small seed. Any differences reported on final plant size are so small (less than 4 inches) that they would likely not have a significant effect on yield.

The size of seed produced by soybeans is determined by a combination of genetic factors for the variety and the environment in which the seed develop. Whether soybeans are large or small, seed for a given variety has the same genetic potential. Therefore, the size of the seed produced on a plant established by planting a small seed will be expected to be the same as those from a plant grown from large seed.

Effects of the seed size on final yield, which is the ultimate concern of growers, appears to be minimal. When shopping for soybean seed, seed quality should be a more important consideration than actual seed size. If smaller-than-normal seed will be used to establish soybeans, check your planter calibration to meter the seed at the proper rate. Excessive seeding rates, resulting from misadjusted planting equipment metering small seed, can result in excessively thick stands that will be more prone to lodging.

Varieties

Soybean varieties are divided into maturity groups according to their relative time of maturity. Varieties of Maturity Group I are nearly full season in northernmost Illinois but are too early for good growth and yield farther south. In extreme southern Illinois, varieties in Maturity Groups IV and V are best adapted.

Traditionally, soybeans grown in the Midwest had indeterminate growth habits; that is, vegetative growth continues beyond the time when flowering begins, continuing generally until seed filling begins. In recent years, a few varieties with determinate growth habits have been developed and released in the Midwest. The main reason for their introduction was to provide varieties that are highly resistant to lodging, which would be most useful in environments where lodging is a yield-limiting factor. The determinate growth habit, which is a genetically controlled trait, stops vegetative growth on the main stem when flowering begins; this produces a relatively short plant that is quite resistant to lodging. With this growth pattern, determinate soybeans must develop adequate leaf material before flowering.

While determinate varieties can be very productive in a favorable environment, they can also disappoint growers when production is attempted in a low-yield environment. Determinate varieties will be most useful and profitable to growers in environments where conditions favor rapid early-season vegetative growth, the same conditions that can possibly lead to lodging problems with indeterminate varieties. Lacking such an environment for soybean production, growers would be wise to use only indeterminate varieties.

The following is a list of public varieties of soybeans that are available in Illinois. If a variety is determinate, the description so notes — all others are indeterminate. Varietal names marked with an asterisk (*) are protected varieties. (See the section entitled "Plant Variety Protection Act.")

Maturity Group I

BSR 101 has more genetic resistance to brown stem rot than does any other public variety in its maturity group. In addition, it has resistance to Phytophthora root rot, race 1. BSR 101 has more lodging resistance and better yield potential than Hardin, which has similar maturity.

Maturity Group II

Beeson 80* is an improved version of the original Beeson variety in that it has resistance to at least seven races of Phytophthora root rot. Maturity is the same

Table 17. Characteristics and Parentage of Soybean Varieties

Maturity group and variety	Parentage and release year[a]	Flower color	Pubescence color	Pod color	Seed luster	Hilum color
I						
BSR 101	L69U40-16-4 X A76-304020 (1985)	purple	gray	tan	intermediate	imblk[b]
II						
Beeson 80	Beeson[8] X Arksoy (1979)	purple	gray	brown	dull	imblk[b]
BSR 201	Pride B-216 X AX901-40-2 (1982)	white	gray	brown	dull	buff
Century 84	Century[5] X Williams 82 (1984)	purple	tawny	brown	shiny	black
CN 290	Beeson X L70-2283 (1983)	purple	gray	brown	shiny	buff
Corsoy 79	Corsoy[6] X Lee 68 (1979)	purple	gray	brown	dull	yellow
Elgin 87	Elgin[5] X Williams 82 (1987)	purple	tawny	brown	shiny	black
Gnome 85	Gnome[6] X Williams 82 (1985)	purple	tawny	tan	shiny	black
Hack	L70T-543G X K1028 (1984)	white	gray	tan	shiny	buff
Preston	Schechinger S48 X Land O'Lakes Max (1985)	purple	gray	brown	intermediate	gray
Wells II	Wells[8] X Arksoy (1978)	purple	gray	brown	dull	imblk[b]
III						
Cartter	Williams[2] X PI88.788 (1986)	white	tawny	tan	shiny	black
Chamberlain	A76-304020 X Land O'Lakes Max (1986)	purple	tawny	brown	shiny	black
Fayette	Williams[2] X PI88.788 (1981)	white	tawny	tan	shiny	black
Harper 87	Harper[6] X Williams 82 (1987)	purple	tawny	brown	shiny	black
Hobbit 87	Hobbit[6] X Williams 82 (1987)	white	tawny	tan	shiny	black
Pella 86	Pella[5] X Williams 82 (1986)	purple	tawny	tan	dull	black
Resnik	A3127[4] X Williams 82 (1986)	purple	tawny	tan	dull	black
Sherman	A72-512 X Pella (1985)	white	gray	brown	shiny	buff
Williams 82	Williams[7] X Kingwa (1981)	white	tawny	tan	shiny	black
IV						
Egyptian	Franklin X J74-5 (1985)	white	tawny	tawny	shiny	black
Lawrence	Calland X Williams (1981)	purple	tawny	tan	dull	black
Pennyrile	Williams X Essex (1987)	white	tawny	tan	dull	black
Pyramid	Franklin X J74-5 (1985)	purple	gray	tan	shiny	imblk[b]
Ripley	Hodgson X V68-1032 (1985)	purple	gray	tan	intermediate	buff
Spencer	A75-305022 X Century	white	tawny	brown	dull	brown
Union	Williams X SL11 (Wayne RpmRps) (1977)	white	tawny	tan	shiny	black
V						
Essex	Lee X 55-7075 (1973)	purple	gray	tan	intermediate	buff
Pershing	(Hill[2] X PI 171450) X Essex (1973)	white	gray	tan	shiny	buff

[a] Superscript indicates the number of crosses in a backcross program.
[b] Imperfect black hilum.

as for Beeson; plants are the same size as Corsoy but have greater lodging resistance.

BSR 201 has resistance to brown stem rot, which makes it particularly useful in fields infested with that disease. In the absence of brown stem rot, BSR 201 is quite competitive in yield with the Century 84 and Corsoy 79 varieties. Resistance to races 1 and 2 of Phytophthora root rot and fair resistance to lodging are characteristics of BSR 201.

Century 84* is an improved version of Century. Century 84 has multirace resistance to Phytophthora (races 1 to 10 and 13 to 15), good lodging resistance, and high yield potential. Maturity and plant size are like that of Century, which it replaces.

CN 290 was developed for use in fields infested with race 3 of the soybean cyst nematode. Maturity of CN 290 is similar to that of Beeson 80. Resistance to races 1 and 2 of Phytophthora root rot and to bacterial pustule is also found in the variety. When SCN is not a problem, yields of CN 290 are less than those of other varieties with similar maturity.

Corsoy 79 is an improved version of Corsoy, similar to the original, with strong emergence and early Group II maturity. Like the original Corsoy, the Corsoy 79 has poor lodging resistance. Unlike the older Corsoy, however, it has resistance to seven races of Phytophthora root rot.

Elgin 87, an improved version of the previously released Elgin, was developed by backcrossing with Williams 82. It has an early Group II maturity and resists lodging. It is resistant to the same races of Phytophthora root rot as Williams 82.

Gnome 85* is an improved version of Gnome, a previously released short-statured variety of determinate growth habit. It has the same yield potential and lodging resistance as did Gnome. Resistance to Phytophthora, however, is the same as for Williams 82.

Hack* has high yield potential and lodging resistance superior to other varieties of similar maturity. It has resistance to Phytophthora root rot, races 1 and 2, and to bacterial pustule.

Preston has higher yield potential than other public varieties of similar maturity. Maturity is very similar to Century and Century 84. Preston is susceptible to both Phytophthora root rot and brown stem rot.

Wells II* is similar in height to Corsoy 79 but matures roughly 2 days earlier and has much better lodging resistance. Whereas the original Wells variety had resistance only to races 1 and 2 of Phytophthora root rot, Wells II has resistance to seven races.

Maturity Group III

Cartter has a relatively early Group III maturity that offers growers resistance to cyst nematode races

Table 18. Average Soybean Yields at Selected Locations in Illinois, 1987-88[a]

Maturity group and variety	Location					
	DeKalb	Monmouth	Urbana	Belleville	Brownstown	Carbondale
	yield, bushels per acre					
I						
BSR 101	61.8					
II						
BSR 201	59.9	50.3	45.9			
Century 84	51.9	47.9	39.6			
Corsoy 79	55.6	42.9	40.2			
Elgin 87	57.5	46.4	43.3			
Gnome 85	56.1	46.4	37.1			
Hack	61.9	48.8	42.6			
Preston	60.2	50.8	43.6			
III						
Cartter	61.6	50.6	39.6	45.1	22.5	43.0
Chamberlain	65.5	57.0	44.9	41.9	26.7	42.2
Fayette				53.5	26.5	
Harper 87	58.8	55.0	41.1	48.0	26.0	46.1
Hobbit 87	60.3	53.7	39.9	37.7	15.7	29.5
Pella 86	55.6	54.4	38.9	44.7	25.1	45.4
Resnik	64.2	58.5	42.2	50.3	27.8	45.6
Sherman	61.1	54.9	43.6	50.0	26.1	51.2
Williams 82			38.7	50.8	27.6	49.1
IV						
Egyptian				58.1	32.6	47.0
Pennyrile				51.5	32.7	44.2
Pixie		53.6	42.4	35.8	21.2	24.1
Pyramid				49.6	31.7	52.0
Ripley		46.6	48.9	46.1	28.2	29.7
Union		46.4	43.9	44.4	29.6	40.7
V						
Essex						41.5
Pershing						36.8

[a] Data compiled by R. Esgar and C. D. Nickell, Agronomy Department, University of Illinois at Urbana-Champaign.

3 and 4, but it lacks resistance to Phytophthora root rot. It was developed from the same breeding program that produced Fayette.

Chamberlain* has a mid-Group III maturity and resistance to brown stem rot disease. It also has resistance to bacterial pustule and races 1 and 2 of Phytophthora root rot. It has good resistance to lodging and has good yield potential.

Fayette is most useful to growers needing resistance to soybean cyst nematode, races 3 and 4. It matures about the same time as Williams 82. Fayette is susceptible to Phytophthora root rot and is moderately resistant to lodging. In the absence of cyst nematode problems, growers should not use Fayette, for other varieties of similar maturity yield better.

Harper 87 was developed by backcrossing Harper with Williams 82 to incorporate into the variety the resistance to Phytophthora root rot. Harper 87 has a maturity and agronomic character essentially the same as the earlier released Harper variety.

Hobbit 87* is an improved version of Hobbit. Resistance to Phytophthora equal to that found in Williams 82 is the notable improvement in this variety. Determinate growth, short stature, lodging resistance, and good yield potential of the original Hobbit are found in Hobbit 87.

Pella 86 is an improved version of Pella. It is a relatively early Group III variety with good lodging resistance and other characters of Pella. The improvement in Pella 86 is in Phytophthora resistance, which is equal to that of Williams 82.

Table 19. Reactions of Soybean Varieties to Phytophthora Root Rot Disease

Maturity Group	Susceptible to Phytophthora root rot	Resistant to races 1 and 2	Resistant to races 1, 2, and others
I	...	BSR 101	...
II	Preston	BSR 201 CN290 Hack	Beeson 80 Century 84 Corsoy 79 Elgin 87 Gnome 85 Wells II
III	Cartter Fayette Sherman	Chamberlain	Harper 87 Hobbit 87 Pella 86 Resnik Williams 82
IV	Egyptian Lawrence Pennyrile Pyramid Spencer	Ripley Union	...
V	Essex Pershing		

Table 20. Soybean Variety Characteristics, 1988

Maturity group and variety	Protected variety[a]	Relative maturity[b]	Lodging	Height	Soybean cyst nematode[c]	
		days	*score*[d]	*inches*	*race 3*	*race 4*
I						
BSR 101	No	−16	2.4	40	S	S
II						
BSR 201	No	− 8	2.3	37	S	S
Century 84	Yes	−11	1.4	38	S	S
Corsoy 79	No	−14	2.7	38	S	S
Elgin 87	Yes	−11	2.1	34	S	S
Gnome 85	Yes	− 6	1.2	22	S	S
Hack	Yes	−13	1.4	34	S	S
Preston	No	− 9	1.7	37	S	S
III						
Cartter	No	− 3	1.7	35	R	R
Chamberlain	Yes	+ 1	1.9	40	S	S
Fayette	No	+ 8	1.7	45	R	R
Harper 87	Yes	+9-15	1.4	35	S	S
Hobbit 87	Yes	− 1	1.1	22	S	S
Pella 86	No	− 3	1.4	35	S	S
Resnik	Yes	− 2	1.5	34	S	S
Sherman	Yes	− 1	1.9	35	S	S
Williams 82	No	+ 5	1.6	40	S	S
IV and V						
Egyptian	No	+16	1.7	38	R	R
Essex	No	+32	2.3	33	S	S
Pennyrile	No	+17	1.3	46	S	S
Pershing	Yes	+26	1.1	29	S	S
Pyramid	No	+14	1.8	44	R	R
Ripley	Yes	+ 8	1.1	25	S	S
Spencer	No	+10	1.1	36	S	S
Union	No	+ 7	2.0	43	S	S

[a] U.S. Protected Variety; see the section entitled "Plant Variety Protection Act."
[b] Relative to Harper 87.
[c] R = resistant, S = susceptible.
[d] 1 = all plants standing; 5 = all plants flat.

Resnik* is a mid-Group III variety, with good yield potential, lodging resistance, and Phytophthora resistance equal to that of Williams 82.

Sherman offers growers an improved yield potential in a variety that matures 2 or 3 days later than Pella. Although Sherman does not have genetic resistance to Phytophthora root rot, it offers yield advantages in environments where that disease is not a problem.

Sprite has determinate growth, making it a short-statured and very lodging-resistant variety. It lacks resistance to Phytophthora root rot and matures early in Group III.

Williams 82 is an improved version of the Williams variety, which was released in the 1970s. It has a late Group III maturity. The Williams 82 has a broad base of resistance to Phytophthora root rot (races 1 to 10, 13 to 15, 17, 18, 21, and 22), allowing it to produce well across a wide range of root-rot infested fields. Plant size and yield potential are the same as in the original Williams variety.

Maturity Group IV

Egyptian is resistant to races 3 and 4 of soybean cyst nematode. It has determinate growth but, because of the time it takes to reach maturity, will not be very short statured. Maturity is about 2 weeks after the Union variety.

Pennyrile has a late Group IV maturity and very good resistance to lodging. It does not offer protection against cyst nematode or Phytophthora but has improved yield potential in the Group IV maturity range.

Pyramid matures about 10 days after Union. Although susceptible to Phytophthora root rot, Pyramid is resistant to soybean cyst nematode, races 3 and 4.

Ripley* has determinate growth and a relative maturity similar to that of Union and Pixie (early Group IV). Short plant stature makes Ripley very resistant to lodging. Although not resistant to Phytophthora root rot, Ripley is reported to carry a high level of field tolerance to the disease.

Spencer offers growers improved yield potential and lodging resistance compared to other varieties of similar maturity. It does not have resistance to cyst nematode or Phytophthora root rot, however.

Union has resistance to Phytophthora, downy mildew, and bacterial pustule. Maturity is early in the Group IV maturity range. Lodging of Union has been a problem in environments that favor abundant vegetative development.

Maturity Group V

Essex has relatively early Group V maturity and is susceptible to soybean cyst nematode. It is resistant, however, to bacterial pustule, downy mildew, and frogeye leaf spot and has field tolerance to Phytophthora root rot. It has very good resistance to lodging.

Pershing has a maturity that is most similar to that of Essex, but the yield potential and lodging resistance of Pershing give it an advantage over Essex. Pershing is susceptible to soybean cyst nematode.

Private varieties and blends

A survey of soybeans that were available for planting in 1988 indicated that more than 800 varieties, blends, and brands were available for the grower's consideration. Each year the University of Illinois conducts the Commercial Soybean Performance Trials on many of the soybeans available. Results are published in an Extension Service circular available in all county Extension offices. The report summarizes the yield, maturity, lodging resistance, height, and shattering resistance of the soybeans evaluated.

Blends (mixtures) of two or more varieties are sometimes marketed for planting. Usually these are identified by a brand name, such as "John Doe 200 Brand." Although most blends are composed of the same varieties in the same proportions each year, neither the Illinois Seed Law nor the Federal Seed Law requires this consistency; therefore, performance of blends may vary from year to year because of variation in components from which they are made.

Plant Variety Protection Act

Congress passed the Plant Variety Protection Act in 1970. This law provides the inventor or owner of a new variety of certain seed-propagated crops the right to exclude others from selling, offering for sale, reproducing, exporting, or using the variety to produce a hybrid, different variety, or blend.

These rights are not automatic. The owner must apply for a certificate of protection. If the owner does not choose to protect the variety, it is public property and anyone may legally reproduce it and sell the seed.

Many varieties of the self-pollinated crops commonly grown in Illinois — such as soybeans and wheat — developed by private industry since 1970 are protected varieties. Many of the varieties developed at state experiment stations also are protected.

The law allows you, if you desire, to save your own production of a protected variety for seed. However, it does place certain restrictions on selling the seed of a protected variety.

Under one provision of the act, the owner may stipulate that the variety be sold by variety name only as a class of certified seed. Seed of varieties protected under this provision of the act cannot be sold by variety name unless it is produced according to the standards and procedures of one of the official seed certification agencies in the United States. In Illinois, this is the Illinois Crop Improvement Association. The sale of uncertified seed of varieties protected in this manner also is a violation of the Federal Seed Act.

If the owner of a protected variety does not subscribe to the certified seed provision of the act, a farmer whose primary occupation is producing food or feed may sell seed of the protected variety to another farmer whose primary occupation is producing crops for food or feed. The second farmer, however, may not sell as seed any of the crop that is produced.

Even if the protected variety is not covered by the certified seed provision of the act, anything advertising the sale of seed of that variety — including farm sale bills — usually is considered an infringement of the owner's rights. Therefore, any person who desires to sell the seed of a protected variety must first obtain permission from the owner of the variety.

The container in which seed of a protected variety is sold should carry a label identifying the seed as that of a protected variety.

Small Grains

Winter wheat

Although both soft red and hard red winter wheat can be grown in Illinois, improved soft wheat varieties are widely adapted in the state; nearly all of Illinois wheat is the soft type. The primary reasons for this are the better yields of soft wheat and the sometimes poor quality of hard wheat produced in our warm and humid climate. It may be difficult to find a market for hard wheat in many parts of the state; therefore, it is advisable to line up a market before planting the crop.

Date of seeding

The Hessian-fly-safe dates for each county in Illinois are given in Table 21. Wheat planted on or after the fly-safe date is much less likely to be damaged by the insect than wheat planted earlier. Wheat planted on or after the fly-safe date also will be less severely damaged in the fall by diseases such as Septoria leaf spot, which is favored by the excessive fall growth usually associated with early planting. Because the aphids that carry the barley yellow dwarf (BYD) virus and the mites that carry the wheat streak mosaic virus are killed by freezing temperatures, the effects of these viruses will be less severe if wheat is planted shortly before the first killing freeze. Finally, wheat planted on or after the fly-safe date will probably suffer less from soil-borne mosaic; most varieties of soft red wheat carry good resistance but may show symptoms if severely infested.

Rate of seeding

Rate-of-seeding trials involving several wheat varieties have been conducted in Illinois. The results of these trials indicate that 1½ bushels (90 pounds) of good seed per acre are adequate when planting at the normal time. The rate should be increased, however, by one-half to one bushel if seeding is delayed by more than 2 weeks past the fly-safe date.

Seed size in wheat varies by variety and by weather during seed production but is usually in the range of 13,000 to 17,000 seeds per pound. At 15,000 seeds per pound, a seeding rate of 1½ bushels per acre provides about 31 seeds per square foot. A stand of 25 to 30 plants per square foot is generally considered the optimum, and a minimum of 15 to 20 plants per square foot is needed to justify keeping a field in the spring.

Seed treatment

Treating wheat seeds with the proper fungicide or mixture of fungicides is a cheap way to help ensure improved stands and better seed quality. The yield from treated seed usually will be 3 to 5 bushels higher than that from untreated seed.

The Department of Plant Pathology suggests that carboxin (Vitavax) or a combination of carboxin with captan, maneb, or thiram be used to treat wheat seed. Vitavax controls loose smut in wheat and barley and should be used if this disease was present in the field where the seed was produced. Because Vitavax is not effective on some other seed-borne diseases that cause seedling blight (such as Septoria), another fungicide should be used along with Vitavax. Should you desire additional information about wheat diseases or seed treatment methods and materials, contact the University of Illinois Department of Plant Pathology or your county Extension adviser.

Table 21. Average Date of Seeding Wheat for Highest Yield

County	Average date of seeding wheat for highest yield	County	Average date of seeding wheat for highest yield	County	Average date of seeding wheat for highest yield	County	Average date of seeding wheat for highest yield
Adams	Sept. 30-Oct 3	Ford	Sept. 23-29	Livingston	Sept. 23-25	Randolph	Oct. 9-11
Alexander	Oct. 12	Franklin	Oct. 10-12	Logan	Sept. 29-Oct. 3	Richland	Oct. 8-10
Bond	Oct. 7-9	Fulton	Sept. 27-30	Macon	Oct. 1-3	Rock Island	Sept. 20-22
Boone	Sept. 17-19	Gallatin	Oct. 11-12	Macoupin	Oct. 4-7	St. Clair	Oct. 9-11
Brown	Sept. 30-Oct. 2	Greene	Oct. 4-7	Madison	Oct. 7-9	Saline	Oct. 11-12
Bureau	Sept. 21-24	Grundy	Sept. 22-24	Marion	Oct. 8-10	Sangamon	Oct. 1-5
Calhoun	Oct. 4-8	Hamilton	Oct. 10-11	Marshall-Putnam	Sept. 23-26	Schuyler	Sept. 29-Oct. 1
Carroll	Sept. 19-21	Hancock	Sept. 27-30			Scott	Oct. 2-4
Cass	Sept. 30-Oct. 2	Hardin	Oct. 11-12	Mason	Sept. 29-Oct. 1	Shelby	Oct. 3-5
Champaign	Sept. 29-Oct. 2	Henderson	Sept. 23-28	Massac	Oct. 11-12	Stark	Sept. 23-25
Christian	Oct. 2-4	Henry	Sept. 21-23	McDonough	Sept. 29-Oct. 1	Stephenson	Sept. 17-20
Clark	Oct. 4-6	Iroquois	Sept. 24-29	McHenry	Sept. 17-20	Tazewell	Sept. 27-Oct. 1
Clay	Oct. 7-10	Jackson	Oct. 11-12	McLean	Sept. 27-Oct. 1	Union	Oct. 11-12
Clinton	Oct. 8-10	Jasper	Oct. 6-8	Menard	Sept. 30-Oct. 2	Vermilion	Sept. 28-Oct. 2
Coles	Oct. 3-5	Jefferson	Oct. 9-11	Mercer	Sept. 22-25	Wabash	Oct. 9-11
Cook	Sept. 19-22	Jersey	Oct. 6-8	Monroe	Oct. 9-11	Warren	Sept. 23-27
Crawford	Oct. 6-8	Jo Daviess	Sept. 17-20	Montgomery	Oct. 4-7	Washington	Oct. 9-11
Cumberland	Oct. 4-5	Johnson	Oct. 10-12	Morgan	Oct. 2-4	Wayne	Oct. 9-11
DeKalb	Sept. 19-21	Kane	Sept. 19-21	Moultrie	Oct. 2-4	White	Oct. 9-11
DeWitt	Sept. 29-Oct. 1	Kankakee	Sept. 22-25	Ogle	Sept. 19-21	Whiteside	Sept. 20-22
Douglas	Oct. 2-3	Kendall	Sept. 20-22	Peoria	Sept. 23-28	Will	Sept. 21-24
DuPage	Sept. 19-21	Knox	Sept. 23-27	Perry	Oct. 10-11	Williamson	Oct. 11-12
Edgar	Oct. 2-4	Lake	Sept. 17-20	Piatt	Sept. 29-Oct. 2	Winnebago	Sept. 17-20
Edwards	Oct. 9-10	LaSalle	Sept. 19-24	Pike	Oct. 2-4	Woodford	Sept. 26-28
Effingham	Oct. 5-8	Lawrence	Oct. 8-10	Pope	Oct. 11-12		
Fayette	Oct. 4-8	Lee	Sept. 19-21	Pulaski	Oct. 11-12		

Depth of seeding

Wheat should not be planted more than 1 to 2 inches deep. Deeper planting may result in poor emergence, particularly with semidwarf varieties because coleoptile length is positively correlated with plant height. Drilling is the best way to ensure proper depth of placement.

Though a drill is best for placing seed at the right depth, a number of growers use a fertilizer spreader to seed wheat. This practice is somewhat risky but often works well, especially if rain falls after planting. The air-flow fertilizer spreaders will usually give a better distribution than the spinner type. If seed is broadcast, the seeding rate should be increased to 2 to 3 bushels per acre to compensate for uneven placement. After broadcast seeding, the field may be rolled with a cultipacker or cultimulcher (with the tines set

Table 22. Characteristics of Public Wheat Varieties Adapted to Illinois Conditions

Name	State, year released	Protected variety[a]	Kernel type	Maturity[b]	Head type[c]	Winter hardiness[d]
Soft wheat						
Argee	Wisconsin, 1976	yes	soft	+8	B	E
Arthur 71	Indiana, 1971	yes	soft	0	S	G
Auburn	Indiana, 1981	yes	soft	+4	S	E
Becker	Ohio, 1985	yes	soft	+3	S	G
Caldwell	Indiana, 1981	yes	soft	. .	S	G
Cardinal	Ohio, 1986	yes	soft	+1	S	G
Clark	Indiana, 1988	yes	soft	−2	T	G
Compton	Indiana, 1984	yes	soft	+3	S	G
Dynasty	Ohio, 1986	yes	soft	+1	B	G
Hart	Missouri, 1977	no	soft	+1	B	F
Pike	Missouri, 1980	yes	soft	+1	S	G
Roland	Illinois, 1977	no	soft	+2	S	G
Saluda	Virginia, 1983	yes	soft	−1	T	F
Scotty	Illinois, 1982	yes	soft	+2	S	G
Tyler	Virginia, 1980	no	soft	+3	S	F
Hard wheat						
Centurk 78	Nebraska, 1978	yes	hard	0	B	G
Newton	Kansas, 1977	yes	hard	−2	B	F
Siouxland	Nebraska, 1984	yes	hard	−1	B	G

[a] U.S. Protected Variety; see the section entitled "Plant Variety Protection Act."
[b] Days earlier (−) or later (+) than Caldwell.
[c] S = smooth (beardless); B = bearded; T = tip-awned.
[d] E = excellent (for example, Argee); G = good (for example, Caldwell); F = fair (for example, Hart).

shallow), or it may be tilled very lightly with a disk or tine harrow to improve seed-soil contact.

Row spacing

Research on row spacing generally shows little advantage for planting wheat in rows that are more narrow than 7 or 8 inches. Yield is usually reduced by wider rows, with a reduction of about 1 to 2 bushels in 10-inch rows.

Seedbed preparation

Wheat requires good seed-soil contact and moderate soil moisture for germination and emergence. Generally, one or two trips with a disk harrow or field cultivator will produce an adequate seedbed if the soil is not too wet. It is better to wait until the soil dries adequately before preparing it for wheat, even if planting is delayed.

No-till drills may be used for wheat, but the soil must be reasonably dry. Do not reduce seeding rates for no-till. Fertilizer materials may be placed on the surface; the drilling action will incorporate them adequately for wheat.

Varieties

Table 22 gives characteristics of publicly developed wheat varieties grown in Illinois. Yield records of most of these varieties are shown in Table 23. Annual reports on yields of public and private varieties are also available in early August from Extension offices.

Intensive management

Close examination of the methods used to produce very high wheat yields in Europe has increased interest in application of similar "intensive" management practices in the United States. Such practices generally include narrow row spacing (4 to 5 inches); high seeding rates (3 to 4 bushels per acre); high nitrogen rates, split into three or more applications; and heavy use of foliar fungicides for disease control and plant growth regulators to reduce height and lodging.

Though work has just begun on testing these practices in Illinois, it has become apparent that responses to these inputs are much less predictable in Illinois than in Europe, primarily because of the very different climatic conditions. Following is a summary of research findings to date:

1. Research in Indiana and other states shows that the response to rows narrower than 7 or 8 inches is quite erratic, with little evidence to suggest that the narrow rows will pay added equipment costs.
2. Seeding rates of 1 to 1½ bushels per acre generally produce maximum yields.
3. Increasing nitrogen rates beyond the recommended rates of 50 to 100 pounds per acre has not increased yields. Splitting the spring nitrogen into two or more applications has not increased yields.
4. Although foliar fungicides are useful if diseases are found, routine use has not been justified.
5. The response to the plant growth regulator Cerone, which is labeled for use on wheat, has not been consistent. Work to date has shown an occasional yield increase from the use of this chemical, especially where the yield levels were above 80 bushels per acre. Where yields are poor due to soil and weather problems, the use of Cerone can result in further yield decreases and should not be considered. The use of this chemical where high yields

Table 22. Characteristics of Public Wheat Varieties Adapted to Illinois Conditions (continued)

Name	Plant height[e]	Standability[f]	Hessian fly[g]	Leaf rust[g]	Powdery mildew[g]	Septoria leaf blotch[g]	Soil-borne mosaic[g]
Soft wheat							
Argee	MT	F	ND	MR	MS	ND	MR
Arthur 71	M	F	R	MS	MS	MS	MR
Auburn	M	G	R	R	R	MR	MR
Becker	S	E	MR	MR	S	MS	MR
Caldwell	M	VG	R	MR	MR	I	MR
Cardinal	M	VG	MR	MR	MS	MS	MS
Clark	M	VG	R	MS	MR	MR	R
Compton	MS	VG	R	MR	MR	MR	MR
Dynasty	M	E	S	MR	MR	MS	MS
Hart	M	F	S	S	S	MS	R
Pike	M	G	MS	MS	S	MS	MR
Roland	MS	E	MS	MS	MS	MS	MR
Saluda	S	G	S	MR	MR	ND	I
Scotty	M	G	MS	MR	R	MS	MR
Tyler	MT	G	MS	S	MR	MS	MR
Hard wheat							
Centurk 78	MT	F	S	MS	S	MS	MR
Newton	MS	G	S	MS	S	ND	MR
Siouxland	MT	G	ND	MR	MR	MR	ND

[e] T = tall (for example, Tyler); M = medium (for example, Caldwell); S = short (for example, Roland).
[f] E = excellent (for example, Roland); VG = very good (for example, Caldwell); G = good (for example, Auburn); F = fair (for example, Hart).
[g] R = resistant; MR = moderately resistant; I = intermediate; MS = moderately susceptible; S = susceptible; ND = not determined.

are expected, and where lodging is likely to be a problem, may be justified.

In summary, although more experiments will be needed to optimize production practices in winter wheat in Illinois, the management recommendations in this section appear to be fairly well matched to the soils and climate of Illinois.

Spring wheat

Spring wheat is not well adapted to Illinois. Because it matures more than 2 weeks later than winter wheat, it is in the process of filling kernels during the hot weather typical of late June and the first half of July. Consequently, yields average only about 50 to 60 percent those of winter wheat.

With the exception of planting time, production practices for spring wheat are similar to those for winter wheat. Because of the lower yield potential, nitrogen rates should be 20 to 30 pounds less than that for winter wheat. Spring wheat should be planted in early spring, as soon as a seedbed can be prepared. If planting is delayed beyond April 10, yields are likely to be very low, and another crop should be considered.

The acreage of spring wheat in Illinois is extremely small, and variety testing has not been extensive. Yields of some varieties are given in Table 24. Using this information and that from other states, the following varieties may be considered for use in Illinois. Those marked with an asterisk are protected varieties.

Era (Minnesota, 1970) is a bearded, midseason-to-late-season semidwarf with good lodging resistance. It is resistant to stem and leaf rust and is tolerant to Septoria, bunt, loose smut, and ergot. Test weight is high.

Marshall* (Minnesota, 1982) is a bearded, semidwarf variety with good standability. It is midseason in maturity and has good resistance to stem and leaf rust and to loose smut.

Olaf (North Dakota, 1973) is a bearded, midseason semidwarf variety with resistance to stem rust, but moderate susceptibility to a number of other diseases. Standability is fair to good.

Wheaton* (Minnesota, 1983) is a bearded, midseason semidwarf with fair standability. Resistance to stem and leaf rust is good.

Rye

Both winter and spring varieties of rye are available, but only the winter type is suitable for use in Illinois. Winter rye is often used as a cover crop to prevent wind erosion of sandy soils. The crop is very winter hardy, grows late into the fall, and is quite tolerant to drought. Rye generally matures 1 or 2 weeks before wheat. The major drawbacks to raising rye are the low yield potential and the very limited market for the crop. It is less desirable than other small grains as a feed grain.

The cultural practices for rye are the same as for wheat. Planting can be somewhat earlier, and the nitrogen rate should be 20 to 30 pounds less than that for wheat because of lower yield potential. Watch for shattering as grain nears maturity. Watch also for the ergot fungus, which replaces grains in the head and is poisonous to livestock.

There has been very little development of varieties specifically for the Corn Belt area, and no yield testing has been done recently in Illinois. Much of the rye seed available in Illinois is simply called common rye; some of this probably descended from Balbo, a variety released in 1933 and widely grown years ago in Illinois. More recently developed varieties that may do reasonably well in Illinois include **Hancock**, released by Wisconsin in 1979, and **Rymin**, released by Minnesota in 1973.

Triticale

Triticale is a crop that resulted from the crossing of wheat and rye in the 1800s. The varieties currently

Table 23. Performance of Public Varieties of Soft Winter Wheat in Illinois

Variety	Belleville, 1987-88	Brownstown, 1986-88	Dixon Springs, 1987-88	Perry, 1986-88	Urbana, 1986-88	DeKalb, 1986-88
	yield, bushels per acre					
Argee	..	..	..	..	..	69
Arthur 71	61	47	55	60	55	55
Auburn	60	44	55	59	69	63
Becker	82	68	73	67	73	63
Caldwell	80	58	69	65	67	62
Cardinal	..	..	80	64	78	..
Compton	72	49	59	59	68	62
Dynasty	70	..	70	..	..	..
Hart	72	55	65	62	65	53
Pike	83	60	70	65	67	58
Roland	69	57	71	62	71	54
Saluda	..	50	81	54	52	..
Scotty	73	48	62	61	65	62
Tyler	78	66	76	58	61	59

Table 24. Performance of Hard Red Spring Wheat, DeKalb, 1985-88

Variety	Yield	Test weight
	bu/acre	*lb/bu*
Era	31	53
Marshall	32	53
Olaf	29	54

available are not well adapted to Illinois and are usually deficient in some characteristic such as winter hardiness, seed set, or seed quality. In addition, they are of feed quality only. They do not possess the milling and baking qualities needed for use in human food.

The potential exists, however, for plant breeders to correct these deficiencies. When this is done, the crop may be valuable for its high protein content and quality.

Cultural practices for triticale are much the same as those for wheat and rye. The crop should be planted on time to help winter survival. As with rye, the nitrogen rate should be reduced to reflect the lower yield potential. With essentially no commercial market for this crop, growers should make certain they have a use for the crop before it is grown. Generally when triticale is fed to livestock, it must be blended with other feed grains.

A limited testing program at Urbana indicates that the crop is generally lower yielding than winter wheat and spring oats. Both spring and winter types of triticale are available, but only the winter type is suitable for Illinois. Caution must be used in selecting a variety because most winter varieties available are adapted to the South and may not be winter hardy in Illinois. Yields of breeding lines tested at Urbana have generally ranged from 30 to 70 bushels per acre.

Spring oats

To obtain high yields of spring oats, plant the crop as soon as you can prepare a seedbed. Yield reductions become quite severe if planting is delayed beyond April 1 in central Illinois and beyond April 15 in northern Illinois. After May 1, another crop should be considered, unless the oats is being used as a companion crop for forage crop establishment, and yield of the oats is not important.

If you are planting oats after corn, you will probably want to disk the stalks; plowing will produce the highest yields but is usually impractical. If you are planting oats after soybeans, disking is usually the only preparation you will need, and it may be unnecessary if the soybean residue is evenly distributed.

Before planting, treat the seed with a fungicide or a combination such as captan plus Vitavax. Several other fungicides and combinations can be used. For more information, see your local Extension adviser or contact the Department of Plant Pathology, University of Illinois, Urbana, Illinois. Seed treatment protects the seed during the germination process from seed- and soil-borne fungi.

Oats may be broadcast and disked in but will yield 7 to 10 bushels more per acre if drilled. When drilling, plant at a rate of 2 to 2½ bushels per acre. If the oats are broadcast and disked in, increase the rate by one-half to one bushel per acre.

For suggestions on fertilizing oats, see the section entitled "Soil Testing and Fertility."

Varieties

In recent years, Illinois has been a leading state in the development of oat varieties. Excellent progress has been made in selecting varieties with high yield, good standability, and resistance to barley yellow dwarf mosaic virus (also called redleaf disease), which is the most serious disease of oats in Illinois.

Table 25 lists the characteristics of oat varieties that are suitable for production in Illinois. Yields of these varieties in Illinois tests are given in Table 26.

Winter oats

Winter oats are not as winter hardy as wheat and are adapted to only the southern third or quarter of the state; U.S. Highway 50 is about the northern limit for winter oats. Because winter oats are somewhat winter tender and are not attacked by Hessian fly, planting in early September is highly desirable. Experience has shown that oats planted before September 15 are more likely to survive the winter than those planted after September 15.

The same type of seedbed is needed for winter oats as for winter wheat. The fertility program should be similar to that for spring oats. Seeding rate is 2 to 3 bushels per acre when drilled.

Norline, Compact, and **Walken** are sufficiently winter hardy to survive some winters in the southern third of the state.

Norline was released by Purdue University in 1960. It tends to lodge more than Walken and Compact. Compact was released by the University of Kentucky in 1968. It is short and more lodging resistant than Norline. Walken was released by the University of Kentucky in 1970. It is more lodging resistant than Norline and Compact but grows a little taller than those varieties.

Spring barley

Spring barley is damaged by hot, dry weather, and therefore is adapted only to the northern part of Illinois. Good yields are possible, especially if the crop is planted in March or early April, but yields tend to be erratic. Markets for malting barley are not established in Illinois, and malting quality may be a problem. Barley can, however, be fed to livestock.

Table 25. Characteristics of Spring Oat Varieties Adapted to Illinois Conditions

Name	State, year released	Kernel color	Maturity[a]	Height	Stand-ability	Resistance[b]		
						Barley yellow dwarf	Stem rust	Smut
Don	Illinois, 1985	white	0	short	fair	I	S	R
Hazel	Illinois, 1985	grayish	4	medium to short	very good	R	S	S
Lang	Illinois, 1977	yellow	..	short	very good	I	S	S
Larry	Illinois, 1981	yellow	0	short	very good	MR	S	S
Noble	Indiana, 1974	yellow	3	medium	good	I	MS	R
Ogle	Illinois, 1981	yellow	4	medium	very good	R	S	S
Otee	Illinois, 1973	white	1	short	good	R	I	R

[a] Days later than Lang.
[b] R = resistant; MR = moderately resistant, MS = moderately susceptible; S = susceptible; I = intermediate.

Table 26. Yield of Spring Oats in Illinois Trials

Variety	DeKalb, 1985-88	Monmouth, 1985-88	Perry, 1985-88	Urbana, 1985-88	
				Yield	Test weight
	bushels per acre				*lb/bu*
Don	116	108	92	118	35
Hazel	106	112	100	130	33
Lang	..	..	..	127	33
Larry	104	104	93	123	34
Noble	107	110	89	119	33
Ogle	110	120	114	133	33
Otee	99	104	93	108	33

Table 27. Performance of Spring Barley, DeKalb, 1985-88

Variety	Yield	Test weight
	bu/acre	*lb/bu*
Glenn	62	43
Morex	63	43
Robust	68	44

Plant spring barley early — about the same time as spring oats. Drill 1½ to 2 bushels of seed per acre. To avoid excessive lodging, harvest the crop as soon as it is ripe. Fertility requirements for spring barley are essentially the same as for spring oats.

Varieties

All varieties included in Table 27 are approved for malting.

Because spring barley is not a large crop in Illinois, Illinois-grown seed is usually nonexistent. Therefore, farmers interested in growing spring barley will need to obtain seed from Wisconsin or Minnesota. All of the following varieties are grown in those states.

Glenn (North Dakota, 1977) is a 6-row barley with rough awns and colorless aleurone. It is slightly shorter than Morex, has better standability, and matures slightly earlier.

Morex (Minnesota, 1978) has semismooth awns, a colorless aleurone, and a 6-row spike. Morex matures about one day earlier than Larker and grows to about the same height, but it is more resistant to lodging.

Robust (Minnesota, 1983) is a 6-row variety with semismooth awns and colorless aleurone. It matures several days later than Morex, stands better, and has about the same height.

Winter barley

Winter barley is not as winter hardy as the commonly grown varieties of winter wheat and should be planted 1 to 2 weeks earlier than winter wheat. Sow with a drill and plant at the rate of 2 bushels of seed per acre.

The fertility requirements for winter barley are similar to those for winter wheat except that less nitrogen is required. Most winter barley varieties are less resistant to lodging than are winter wheat varieties. Winter barley cannot stand "wet feet"; therefore, it should not be planted on land that tends to be low and wet. The barley yellow dwarf virus is a serious threat to winter barley production.

Varieties

The following section lists public winter barley varieties that are available in Illinois, and Table 28 summarizes their performance. The state and year of release are given in parentheses just after the name.

Barsoy (Kentucky) matures very early and yields

Table 28. Performance of Winter Barley in Illinois

Variety	Brownstown				Urbana			
	1979-84[a]		1987		1979-85[a]		1987	
	Yield	Test weight	Yield	Test weight	Yield	Test weight	Yield	Test weight
	bu/A	*lb/bu*	*bu/A*	*lb/bu*	*bu/A*	*lb/bu*	*bu/A*	*lb/bu*
Barsoy	70	46	..	..	73	48	..	..
Maury	72	43	49	42	86	44	53	34
Pike	68	44	..	..	81	45	..	..
Wysor	..	..	78	44	..	..	78	41

[a] Trial could not be planted in 1985 because of wet weather at Brownstown. All varieties were completely winter-killed at both locations in 1986 and were extensively damaged in 1988, especially at Urbana.

well but is probably the least winter hardy of the varieties tested.

Maury (Virginia, 1977) matures 4 to 5 days later than Pike. It grows 3 to 5 inches taller but has better lodging resistance. Maury is tolerant to the barley yellow dwarf virus. Although it is not as winter hardy as Pike, it should survive all but the most severe winters.

Monroe (Virginia, 1976) was selected from the same cross as Maury and carries the same tolerance to the barley yellow dwarf virus. Like Maury, Monroe is not as winter hardy as Pike but should still survive all but the most severe winters. It matures 1 to 2 days later than Maury.

Pike* (Indiana, 1975) matures as early as Barsoy and is more winter hardy. Pike is a protected variety.

Wysor (Virginia, 1985) is a high-yielding variety with good winter hardiness. It matures a few days later than Pike. It has good disease resistance.

Grain Sorghum

Although grain sorghum can be grown successfully throughout Illinois, its greatest potential is in the southern third of the state. It is adapted to almost all soils, from sand to heavy clay. Its greatest advantage over corn is tolerance of moisture extremes. Grain sorghum usually yields more than corn when moisture is in short supply, though it seldom yields as much as corn under optimum conditions.

Fertilization. The phosphorus and potassium requirements of grain sorghum are similar to those of corn. The response to nitrogen is somewhat erratic, due largely to the extensive root system's efficiency in taking up soil nutrients. For this reason, and because of the lower yield potential, the maximum rate of nitrogen suggested is about 125 pounds per acre. For sorghum following a legume .such as soybeans or clover, this rate may be reduced by 20 to 40 pounds.

Planting. Sorghum should not be planted until soil temperature is at least 65°F. In the southern half of the state, mid-May is considered the starting date; late May to June 15 is the planting date in the northern half of the state.

Sorghum emerges more slowly than corn and requires a relatively fine and firm seedbed. Planting depth should not exceed 1½ inches, and ¾ to 1 inch is considered best. Because sorghum seedlings are slow to emerge, growers should use caution when using reduced- or no-till planting methods. Surface residue usually keeps the soil cooler and may harbor insects that can attack the crop, causing serious stand losses, especially when the crop is planted early in the season.

Population and row spacing. Row-spacing experiments have shown that 20- to 30-inch rows produce far better than 40-inch rows. Aim for a plant stand of 50,000 to 100,000 plants per acre, with the lower population on droughtier soils. Four to 6 plants per foot of row in 30-inch rows at harvest and 2 to 4 plants per foot in 20-inch rows are adequate. Plant 30 to 50 percent more seeds than the intended stand. Sorghum may also be drilled using 6 to 8 pounds of seed per acre.

Weed control. Because emergence of sorghum is slow, controlling weeds presents special problems. Suggestions for chemical control of weeds are given in the back of this handbook. As with corn, a rotary hoe is useful before weeds become permanently established.

Harvesting and storage. Timely harvest is important. Rainy weather after sorghum grain reaches physiological maturity may cause sprouting in the head, weathering (soft and mealy grain), or both. Harvest may begin when grain moisture is 20 percent or greater, if drying facilities are available. Sorghum dries very slowly in the field. Because sorghum does not die until frost, the use of a desiccant (sodium chlorate) can reduce the amount of green plant material going through the combine, making harvest easier.

Marketing. Before planting, check on local markets. Because the acreage in Illinois is limited, many elevators do not purchase grain sorghum.

Grazing. After harvest, sorghum stubble may be used for pasture. Livestock should not be allowed to graze for one week after frost because the danger of prussic acid or hydrocyanic acid (HCN) poisoning is especially high. Newly frosted plants sometimes develop tillers high in prussic acid.

Miscellaneous Crops

A large number of crops that will grow in Illinois have not been produced commercially. A few others have been produced on a limited scale. This section provides a brief introduction to these crops. Production information is given for a few crops that have been tested and grown in the state.

Sunflowers

Two kinds of sunflowers are produced in Illinois, the oilseed sunflower and the nonoil, or confectionary, sunflower. The oilseed sunflower bears a relatively small seed with an oil content of 38 to 50 percent. The hull is thin and dark and adheres closely to the kernel. The oil is highly regarded as a salad oil, and because of its high smoke point is unusually good for frying food and popping corn. The meal is used as a protein supplement in livestock rations; because sunflower meal is deficient in lysine, however, it cannot be used as the only source of protein in rations for nonruminant animals. The protein and crude fiber content vary with the method of processing. The confectionary (nonoil) sunflower bears a larger seed with a lower oil content. The hull is also lighter in color, is usually striped, and separates easily from the kernel. Confectionary sunflowers are used for human food and bird feed.

Planting. Sunflowers should be planted at the same time as corn. Because many of the hybrids offered for sale in Illinois reach physiological maturity (25- to 30-percent moisture) in 90 to 100 days, they may also follow small grain plantings as second crops. Because sunflowers do not host the soybean cyst nematode, they are a possible substitute for soybeans as a double crop.

Oilseed sunflowers should be planted at a population rate that will establish 20,000 to 25,000 plants per acre on soils with good water-holding capacity and 16,000 to 20,000 plants per acre on more coarsely textured soils with relatively low water-holding capacity. Confectionary sunflowers should be planted at a lower population rate to ensure larger seed size.

The recommended planting depth is 1½ to 2 inches, or about the same as that recommended for corn. Sunflowers perform best when planted in 20- to 30-inch rows, but planting in wider rows will also produce good yields.

Harvesting. Agronomists in North Dakota recommend harvesting after seed moisture has dropped to 18 or 20 percent. Losses are greatly reduced when sunflower attachments are used on the conventional combine head. These attachments are long panlike guards extending from the cutter bar.

Problems. Because sunflowers are not commonly grown in Illinois, it is important to locate a market before planting a crop.

Feeding by birds can become a serious problem in any sunflower field and is most likely to occur near farmsteads and wooded areas. Insects and diseases can also damage sunflower crops. The severity of the damage will increase as the acreage of sunflowers increases in a community and will vary from season to season.

Oilseed rape (Canola)

Rape, a member of the mustard family, is grown as a traditional oilseed crop in a number of other countries but has not been grown widely in the United States. Both spring and winter types exist, but the poor performance of this crop in hot weather suggests that the winter type will be most likely to succeed in Illinois. Most varieties of this type are presently of

European origin. Their winter hardiness under Illinois conditions is not known.

Unimproved varieties and landraces of rapeseed contain erucic acid as part of the oil and high levels of toxic glucosinolates in the meal. Both of these antinutritional factors have been reduced or eliminated in some varieties (double-low or double-zero varieties). Canadian workers designated this group of improved varieties as Canola. Such varieties have better commercial potential than those containing one or both of the antinutritional factors because both the oil and meal from double-low varieties can be used. Rapeseed oil is of high quality, and the meal can be used as a livestock feed supplement.

Winter rapeseed has been grown only on a limited scale in Illinois, and cultural practices are not well established. The crop is generally seeded 2 to 3 weeks before the optimum time to sow wheat. The seed is very small, and 5 to 6 pounds per acre seeded shallowly with a drill or forage seeder should be sufficient to establish a stand. Fertility requirements are much the same as for winter wheat, except that the per-acre nitrogen rate should be 20 to 40 pounds higher than for wheat. The crop normally will be ready for harvest a few days to a week before winter wheat and should be harvested in a timely and careful manner to avoid shatter loss. With the limited acreage, it is not yet known what insects and diseases will attack this crop in Illinois.

As no established market for rapeseed exists in Illinois, producers should line up a market before growing this crop. There are a few processing plants in the United States, and a considerable amount of rapeseed moves in international trade.

Buckwheat

Buckwheat may mature in 75 to 90 days. It may be planted as late as July 10 to 15 in the northern part of the state and in late July in southern Illinois. The crop is sensitive to both cold and hot weather. It will be killed by the first frost in the fall. Yields will be disappointingly low if it blooms during hot weather.

The market for buckwheat is limited unless you plan to use it for livestock feed. Be sure of a market before you plant it.

Crambe

Crambe, another member of the mustard family, was promoted and grown on a limited acreage a number of years ago as a source of erucic acid, which has a number of industrial uses. This crop is seeded in the early spring and does not thrive in hot weather. This trait has led to erratic performance, and crambe has failed to become an established crop. Although there are some improved varieties and interest in the crop has increased in some areas, the susceptibility of this crop to warm temperatures is likely to limit its production in Illinois.

Jerusalem artichoke

This relative of the sunflower has been grown, mostly by gardeners, for its edible tubers. In 1983, the crop was promoted in Illinois, and a number of producers planted it even though the commercial market for the tubers is very small. The crop proved to be quite sensitive to drought, and yields were low. Other than being grown from tubers rather than from seed, cultural practices for the Jerusalem artichoke are similar to those for the sunflower. Harvest requires a potato harvester, modified for the small tuber size of this crop. Tubers that escape harvest can establish as serious weeds in succeeding crops.

Grain amaranth

This crop, which is a type of pigweed selected for seed production, was a traditional crop of Central and South America before the Spanish Conquest. The seeds are generally ground into flour, which is sold mainly in health-food outlets. The nutritional quality of the seeds is quite good compared to that of cereal grains. While efforts are underway to improve this crop genetically, limited experience in Illinois has shown most of the existing varietal types to be somewhat poorly adapted to field-scale production; standability and seed shatter can be problems. At the present time, amaranth, which is generally produced as a row crop, has a very limited market.

Other crops

Many other crops can grow in Illinois, but markets for them are not established or are very small. Some of these crops require a considerable amount of hand labor, and competing with areas of the world where labor is very cheap will be difficult.

Crops that remain undeveloped in Illinois include industrial crops such as meadowfoam and cuphea (specialty oil crops) and kenaf, a possible source of paper pulp. There are several medicinal crops such as belladonna and evening primrose and spice crops such as ginseng and sesame. A number of grain legumes such as mungbean, various edible dry beans, and lupines could also be produced, though pest problems could be serious if any of these were grown on a commercial scale.

While there is plenty of opportunity for individuals or small groups of entrepreneurs to explore production and marketing of the crops mentioned in this section, it is difficult to foresee a substantial move away from corn, soybeans, and wheat in favor of any of these crops. Nutrients required in very large amounts by people and livestock include carbohydrates, protein, and oil — a good balance of these is provided by the crops now grown in this state.

Hay, Pasture, Silage, and Seed Pollination

High yields

Thick, vigorous stands of grasses and legumes are needed for high yields. A thick stand of grass will cover nearly all the ground. A thick stand of alfalfa is about 30 plants per square foot at the end of the seeding year, 10 to 15 plants per square foot the second year, and 5 to 7 plants per square foot for the succeeding years.

Vigorous stands are created and maintained by choosing disease- and insect-resistant varieties that grow and recover quickly after harvest, by fertilizing adequately, by harvesting at the optimum time, and by protecting the stand from insects.

Establishment

Spring seeding date for hay and pasture species in Illinois is late March or early April — as soon as a seedbed can be prepared. Exceptions are seedings that are made in a fall-seeded, winter annual companion crop; for such seedings, seed hay and pasture species about the time of the last snow.

Sowing hay and pasture species into spring oats in the spring should be done when the oats are seeded, as early as a seedbed can be prepared.

Spring seedings are more successful in the northern half of Illinois than in the southern half. The frequency of success in the southern one-quarter to one-third of the state indicates that late-summer seedings may be more desirable than spring seedings.

Late-summer seeding date is August 10 in the northern quarter of Illinois, August 30 in central Illinois, and September 15 in the southern quarter of Illinois. Seedings should be made close to these dates, and no more than 5 days later, to assure that the plants become well established before winter. Late-summer seedings that are made extremely early may suffer from drought following germination.

Seeding rates for hay and pasture mixtures are shown in Table 38 on page 36. These rates are for seedings made under average conditions, either with a companion crop in the spring or without a companion crop in late summer. Higher rates may be used to obtain high yields from alfalfa seeded without a companion crop in the spring. Seeding rates higher than described in Table 38 have proven economical in northern and central Illinois when alfalfa was seeded as a pure stand in early spring and two or three harvests were taken in the seeding year. In northern and central Illinois, but not in south-central Illinois, seeding alfalfa at 18 pounds per acre has produced yields 0.2 to 0.4 ton higher than seeding at 12 pounds per acre.

The two basic methods of seeding are band seeding and broadcast seeding. With band seeding, a band of phosphate fertilizer (0-45-0) is placed about 2 inches deep in the soil with a grain drill; then the forage seed is placed on the soil surface directly above the fertilizer band (Figure 3). Before the forage seeds are dropped, the fertilizer should be covered with soil, which occurs naturally when soils are in good working condition. A presswheel should roll over the forage seed to firm the seed into the soil surface. Many seeds will be placed one-eighth to one-fourth inch deep with this seeding method.

With broadcast seeding, the seed is spread uniformly over the prepared soil surface; then the seed is pressed into the soil surface with a corrugated roller. The fertilizer is applied at the early stages of seedbed preparation. The seedbed is usually disked and

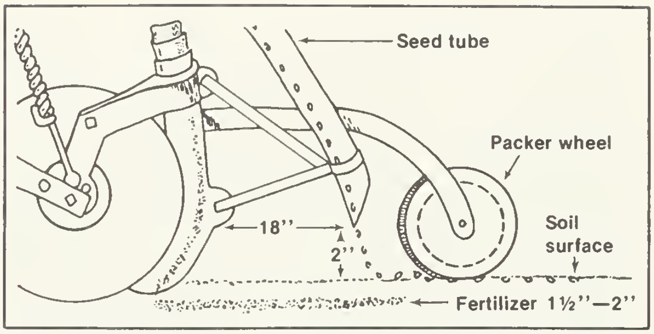


Figure 3. Placement of seed and high-phosphate fertilizer with grain drill.

smoothed with a harrow. Most soil conditions are too loose after these tillage operations and should be firmed with a corrugated roller before seeding. The best seeding tool for broadcast seeding is the double corrugated roller seeder.

Which is the better seeding method? Illinois studies have shown that band seeding often results in higher alfalfa yields than broadcast seedings for August and spring seedings. Seedings on soils that are low in phosphorus yield more from band seeding than from broadcast seeding. Early seeding on cold, wet soils is favored by banded phosphorus fertilization. The greater yield from band seeding may be a response to abundant, readily available phosphorus from the banded fertilizer. Broadcast seedings may yield as high as band seedings when the soils are medium to high in phosphorus-supplying capacity and are well drained, so that they warm up quickly in the spring.

Forage crop seeds are small and should be seeded no deeper than one-fourth to one-half inch. The seeds should be in close contact with soil particles. The double corrugated roller seeder and the band seeder with press-wheels roll the seed into contact with the soil and are the best known methods of seeding forages.

Fertilizing and liming before or at seeding

Lime. Apply lime at rates suggested in Figure 7, page 39. If rate requirements are in excess of 5 tons, apply half before the primary tillage (in most cases, plowing) and half before the secondary tillage (harrowing or disking). For rates of less than 5 tons, make a single application, preferably after plowing, although applying either before or after plowing is acceptable.

Nitrogen (N). No nitrogen should be applied for legume seedings on soils with an organic-matter content above 2.5 percent. Up to 20 pounds of nitrogen per acre may help assure rapid seedling growth of legume-grass mixtures on soils with less than 2.5-percent organic matter. When seeding a pure grass stand, 50 to 100 pounds of nitrogen per acre in the seedbed are suggested. If band seeding, apply nitrogen with phosphorus through the grain drill. For broadcast seedings, apply broadcast with phosphorus and potassium.

Phosphorus (P). Apply all phosphorus at seeding time (Tables 55 and 56) or broadcast part of it with potassium. For band seeding, reserve at least 30 pounds of phosphate (P_2O_5) per acre to be applied at seeding time. For broadcast seeding, broadcast all the phosphorus with the potassium, preferably after primary tillage and before final seedbed preparation.

Potassium (K). Fertilize before or at seeding. Broadcast application of potassium is preferred (Tables 56 and 57). For band seeding, you can safely apply a maximum of 30 to 40 pounds of potash (K_2O) per acre in the band with phosphorus. The response to band fertilizer will be mainly from phosphorus unless the K soil test is very low (perhaps 100 pounds per acre or less). For broadcast seeding, apply all the potassium after the primary tillage. You can apply up to 600 pounds of K_2O per acre in the seedbed without damaging seedlings if the fertilizer is incorporated.

Fertilization

Nitrogen. See the section entitled "Soil Testing and Fertility," the subsection about nitrogen.

Phosphorus. This nutrient may be applied in large amounts, adequate for 2 to 4 years. The annual needs of a hay or pasture crop are determined from yield and nutrient content of the forage harvested (Table 56). Grasses, legumes, and grass-legume mixtures contain about 12 pounds of P_2O_5 (4.8 pounds of P) per ton of dry matter. Total annual fertilization needs include the maintenance rate (Table 56) and any needed build-up rate (Table 55).

Potassium. Because potassium helps the plant convert nitrogen to protein, grasses need large amounts of potassium to balance high rates of nitrogen fertilization. As nitrogen rates are increased, the nitrogen percent in the plant tissue also increases. If potassium is deficient, however, some nitrogen may remain in the plant as nonprotein nitrogen.

Legumes feed heavily on potassium. Potassium, a key element in the maintenance of legumes in grass-legume stands, is credited with improving winter survival.

Annual potassium needs are determined from yield, nutrient content in the forage that is harvested, and nutrient build-up requirements of a particular soil (Tables 56 and 57). Grasses, legumes, and grass-legume mixtures contain about 50 pounds of K_2O (41.5 pounds of K) per ton of dry matter.

Boron (B). Symptoms of boron deficiency appear on second and third cuttings of alfalfa during droughty periods in some areas of Illinois. But yield increases from boron fertilization have been infrequent. Application of boron on soils with less than 2-percent organic matter is recommended for high-yielding alfalfa production in Illinois. If you suspect a boron deficiency,

topdress a test strip in your alfalfa fields with 30 pounds per acre of household borax (3.3 pounds of boron). For general application, have boron added to the phosphorus-potassium fertilizer.

Management

Seeding year. Hay and pasture crops seeded into a companion crop in the spring will benefit by early removal of the companion crop. Oats, wheat, or barley should be removed when the grain is in the milk stage. If these small grains are harvested for grain, it is important to remove the straw and stubble as soon as possible. As small-grain yields increase, the underseeded legumes and grasses face greater competition, and fewer satisfactory stands are being established by the companion-crop method. Forage seedings established with a companion crop may have one harvest taken by late August in northern Illinois and, occasionally, two harvests by September 10 in central Illinois and by September 25 in southern Illinois.

Spring-seeded hay crops and pastures without a companion crop should be ready for harvest 65 to 70 days after an early April seeding. Weeds very likely must be controlled about 30 days after seeding unless a preemergence herbicide was used. A postemergence herbicide, 2,4-DB, is effective against most broadleaf weeds. Grassy weeds are effectively controlled by Fusilade, Poast, and Velpar. Label clearance is pending for Fusilade and Poast. Velpar is labeled for use on alfalfa that is one year old. Follow label directions. Leafhoppers often become a problem between 30 to 45 days after an early April seeding and must be controlled to obtain a vigorous, high-yielding stand.

Second and third harvests may follow the first harvest at 35- to 40-day intervals. The last harvest of the season should be in late August for the northern quarter of Illinois, by September 10 for the central section, and by September 20 for the southern quarter of Illinois.

Established stands. Maximum dry-matter yield from alfalfa and most forages is obtained by harvesting or grazing the first cutting at nearly full bloom and harvesting every 40 to 42 days thereafter until September. This management produces a forage that is relatively low in digestibility. Such forage is suitable for livestock on maintenance, will produce slow weight gain, and can be used in low-performance feeding programs. In contrast, high-performance feeding programs require a highly digestible forage. The optimum compromise between high digestibility and dry-matter yield of alfalfa is to harvest or graze the first cutting at the late-bud to first-flower stage and to make subsequent cuttings or grazings at 32- to 35-day intervals. Rotational grazing is essential to maintaining legumes in pastures. A rotational grazing program should provide for 5 to 7 days of grazing and 30 to 35 days of rest.

Because a high level of root reserves (sugars and starches) is needed, winter survival and vigor of spring growth are greatly affected by the timing of the fall harvest. Following a harvest, root reserves decline as new growth begins. About 3 weeks after harvesting, root reserves are depleted to a low level, and the top growth is adequate for photosynthesis to support the plant's needs for sugars. From this point, root reserves are replenished gradually until harvest or until the plant becomes dormant in early winter. Harvests made in September and October affect late-fall root reserves of alfalfa more than do summer harvests. After the September harvest, alfalfa needs a recovery period until late October to restore root reserves. On well-drained soils in central and southern Illinois, a "late" harvest may be taken after plants have become dormant in late October or early November.

Pasture establishment

Many pastures can be established through a hay crop program. Seedings are made on a well-prepared, properly fertilized seedbed. If it is intended that the hay crop becomes a pasture, the desired legume and grass mixture should be seeded. When grasses and legumes are seeded together, 2,4-DB is the herbicide that can be used for broadleaf weed control. For 2,4-DB to be most effective, apply it about 30 days after seeding, when the legumes are 2 to 4 inches tall and the weeds less than 4 inches tall.

Pasture renovation

Pasture renovation usually means changing the plant species in a pasture to increase the pasture's quality and productivity. Improving the fertility of the soil is basic to this effort. A soil test helps identify the need for lime, phosphorus, and potassium — the major nutrients important to establishing new forage plants.

Before seeding new legumes or grasses into a pasture, reduce the competition from existing pasture plants. Tilling, overgrazing, and herbicides — used singly or in combination — have proven useful in subduing existing pasture plants.

For many years, tilling (plowing or heavy disking) has been used to renovate pastures; but success has been variable. Major criticisms have been that tilling can cause erosion, that the pasture supply for the year of seeding is usually limited, and that a seeding failure would leave no available permanent vegetation for pasturing or soil protection.

No-till seeding of new pasture plants into existing pastures began when herbicides and suitable seeders were developed. The practice of using a herbicide to subdue existing pasture plants and then seeding with a no-till seeder has proven very successful in many research trials and farm seedings. Following are eight basic steps to no-till pasture renovation.

1. Graze the pasture intensively for 20 to 30 days

before the seeding date to reduce the vigor of existing pasture plants.

2. Lime and fertilize, using a soil test as a guide. Soil pH should be between 6.5 and 7.0. Desirable test levels of phosphorus and potassium vary with soil type; phosphorus should be in the range of 40 to 50 pounds per acre, and potassium in the range of 260 to 300 pounds per acre. For more information, see the section entitled "Soil Testing and Fertility."
3. One or 2 days before seeding, apply a herbicide to subdue the vegetation. Gramoxone Super (paraquat) and Roundup (glyphosate) are approved for this purpose.
4. Seed the desired species, using high-yielding varieties. Alfalfa and red clover are the legumes with higher yields and are often the only species seeded into a pasture that has a desirable grass species and in which Gramoxone Super is going to be used in preference to Roundup. To seed, use a no-till drill that places the seed in contact with the soil.
5. Seed in early spring throughout the northern two-thirds of Illinois and in late August throughout the southern three-fourths of Illinois.
6. Apply insecticides as needed. Soil insects that eat germinating seedlings are more prevalent in southern Illinois than in northern Illinois, and a soil insecticide may be needed. Furadan has been approved for this use. Leafhoppers will be present throughout Illinois in early summer and during most of the growing season. They must be controlled, especially in spring-seeded pastures, because they are devastating to new alfalfa seedlings. Several insecticides are approved; for more information, see Cooperative Extension Circular 899, *Insect Pest Management Guide: Field and Forage Crops.* Well-established alfalfa plants are injured but not killed by leafhoppers; red clover and grass plants are not attacked by leafhoppers.
7. Initiate grazing 60 to 70 days after spring seedings and not until the next spring for late-August seedings. Spring-seeded alfalfa and red clover should be at about 50-percent bloom. Alfalfa and red clover that are seeded in late August should be in the late-bud to first-flower stage of growth when grazing begins. Use rotational grazing. Graze 5 to 7 days and rest 28 to 30 days; for slightly lower-quality and lower-yielding pastures, graze 10 days and rest 30 days.
8. Fertilize pastures annually on the basis of estimated crop removal. Each ton of dry matter from a pasture contains about 12 pounds of phosphate (P_2O_5) and 50 to 60 pounds of potash (K_2O). Do not use nitrogen on established pastures in which at least 30 percent of the vegetation is alfalfa, red clover, or both.

Selection of pasture seeding mixture

Alfalfa is the single best species for increasing yield and improving the quality of pastures in Illinois. Red clover produces very well in the first 2 years after seeding but contributes very little after that. Birdsfoot trefoil establishes slowly and increases to 40 to 50 percent of the yield potential of alfalfa. Mixtures of alfalfa at 8 pounds and red clover at 4 pounds per acre or of birdsfoot trefoil at 4 pounds and red clover at 4 pounds per acre have demonstrated high yield. Red clover diminishes from the stand about the third year; and the more persistent species, alfalfa or birdsfoot trefoil, increases to maintain a high yield level for the third and subsequent years.

Management to improve pastures

The yield and quality of many pastures can be improved by fertilization. The soil pH is basic to any fertilization program. Pasture grasses tolerate a lower soil pH than do hay and pasture legumes. For pastures that are primarily grass, a minimal pH should be 6.0. A pH of 6.2 to 6.5 is more desirable because nutrients are more efficiently utilized in this pH range than at lower pH values. Lime should be applied to correct the soil acidity to one-half plow depth. This liming is effective half as long as when a full rate is applied and plowed into the plow layer. Consequently, pastures will usually require liming more often (but at lower rates) than will cultivated fields.

Phosphorus and potassium needs are assessed by a soil test. Without a soil test, the best guess is to apply what the crop removes. Pasture crops remove about 12 pounds of phosphate (P_2O_5) and 50 pounds of potash (K_2O) per ton of dry matter. Very productive pastures yield 5 to 6 tons of dry matter per acre; moderately productive pastures yield 3 to 5 tons; and less productive pastures, 1 to 3 tons.

Rotational grazing of grass pastures results in greater production (animal product yield per acre) than does continuous grazing, except for Kentucky bluegrass pastures. Pastures that include legumes need rotational grazing to maintain the legumes. A rotational grazing plan that works well is 5 to 7 days' grazing with 28 to 30 days' rest, which requires five to six fields. This plan provides the high-quality pasture needed by growing animals and dairy cows. A less intense grazing plan for beef cow herds, dry cows, and stocker animals is 10 days' grazing with 30 days' rest, which requires four fields.

Weed control is usually needed in pastures. Clipping pastures after each grazing cycle helps in weed control, but herbicides may be needed for problem areas. Banvel and 2,4-D are effective on most broadleaf weeds. Banvel is more effective than 2,4-D for most conditions but also has more restrictions. Do not graze

dairy animals or feed harvested forage from these fields until 60 days after treatment with Banvel. Remove meat animals from Banvel-treated pastures 30 days before slaughter. Restrictions for 2,4-D apply to milk cows, which should not be grazed on treated pasture for 7 days after treatment. Thistles can usually be controlled by 2,4-D or Banvel, although repeated applications of the herbicide may be necessary. Multiflora rose may be controlled with Banvel applied in early spring, when the plant is actively growing, but before flower bud formation.

Species and varieties

Alfalfa is the highest-yielding perennial forage crop suited to Illinois, and its nutritional qualities are nearly unsurpassed. Alfalfa is an excellent hay crop species and, with proper management, may be used in pastures, as already mentioned.

Bloat in ruminant animals often is associated with alfalfa pastures. Balancing soil fertility, including grasses in mixtures with alfalfa, maintaining animals at good nutritional levels, and using bloat-inhibiting feed amendments are methods to reduce or essentially eliminate the bloat hazard.

Many varieties of alfalfa are available. Some have been privately developed, some developed at public institutions. Private varieties usually are marketed through a few specific dealers. Not all varieties are available in Illinois.

An extensive testing program has been under way at the University of Illinois for many years. The performance of alfalfa varieties listed in Table 29 is based on test data compiled since 1961. Some varieties have been tested every year since then; others have been tested only 3 or 4 years. Each variety in this list, however, has been in tests at least 3 years.

Bacterial wilt is one of the major diseases of alfalfa in Illinois. Stands of susceptible varieties usually decline severely in the third year of production and may die out in the second year under intensive harvesting schedules. Moderate resistance to bacterial wilt enables alfalfa to persist as long as 4 or 5 years. Varieties listed as resistant usually persist beyond 5 years.

Phytophthora root rot is a major disease of alfalfa grown on poorly drained soils, primarily in the northern half of Illinois. This disease attacks both seedlings and mature plants. The root develops a black lesion, which progresses and rots the entire root. In mature stands, shortened taproots are a symptom of this disease. Many alfalfa varieties with high-yield performance have resistance or moderate resistance to phytophthora root rot.

Anthracnose is an important disease in the southern half of Illinois and may be important in northern Illinois during warm, humid weather. The disease causes the stem and leaves to brown, with the tip of the stem turning over like a hook. The fungus causes a stem lesion, usually diamond-shaped in the early stages, which enlarges to completely encircle the stem. Many alfalfa varieties with high-yield performance have resistance or moderate resistance to anthracnose.

Table 29. Leading Alfalfa Varieties Tested Three Years or More in Illinois

Brand, variety	Bacterial wilt[b]	Percentage of yield of check varieties[a]		
		Northern Illinois	Central Illinois	Southern Illinois
Americana Acclaim	R	0.00	109.87	0.00
Americana PH2121	HR	98.64	106.23	0.00
Apollo	R	105.40	106.70	0.00
Apollo II	R	109.12	103.74	0.00
Armor	R	107.20	105.13	99.68
Arrow	HR	110.68	101.94	104.56
Blazer	R	111.22	105.02	110.29
Challenger	R	104.93	0.00	103.82
Cimarron	HR	105.19	101.80	102.75
Dart	HR	105.71	106.31	101.09
DeKalb BR 120	HR	105.64	105.42	104.76
Decathlon	HT	101.02	0.00	108.69
Duke	HR	105.97	100.00	0.00
Elevation	R	107.07	110.91	0.00
Embro A-54	R	105.04	105.76	104.50
Endure	R	108.21	0.00	108.25
Epic	R	107.39	107.82	103.51
Excalibur	R	96.59	107.57	0.00
Expo	R	102.85	107.90	0.00
Funk's G-2815	R	107.18	104.88	100.40
Funk's G-7730	HR	106.04	105.22	100.30
Garst 630	HR	0.00	102.74	0.00
Garst 636	HR	105.85	103.27	0.00
Honeoye	MR	104.90	99.40	103.96
Husky	R	108.06	108.10	0.00
Jubilee	R	107.54	106.33	0.00
Magnum	HR	105.05	105.79	0.00
Magnum Plus	R	101.37	100.84	0.00
Mercury	R	116.10	110.10	0.00
Milkmaker	R	102.79	109.57	0.00
Oneida	R	98.92	97.96	103.55
Peak	R	109.06	108.90	0.00
Perry	R	91.20	105.34	102.72
Pioneer BR 531	R	104.75	112.00	110.00
Raidor	R	105.93	101.75	0.00
Saranac	MR	105.70	102.80	102.10
Saranac AR	MR	101.37	104.47	103.78
Surpass	R	103.51	105.62	0.00
Thorobred	R	103.30	110.20	0.00
Thunder	HR	0.00	109.60	0.00
Total	R	107.94	99.02	102.69
Trident	MR	105.71	103.90	102.73
Vancor	R	104.02	104.37	108.49
Vernal	R	100.81	100.37	102.52
Voris VA-77	HR	106.81	106.31	99.40

[a] Check varities = Baker, Riley, Saranac AR, and Vernal.
[b] HR = highly resistant; R = resistant; MR = moderately resistant; HT = highly tolerant.

Verticillium wilt is a root-rot disease that is similar to bacterial wilt. Verticillium wilt develops slowly, requiring about 3 years before plant loss becomes noticeable. Associated with cool climates and moist soils, this fungus is gradually spreading southward in Illinois. Producers in the northern quarter of Illinois should seek resistant varieties; and producers in the rest of the northern half of the state should observe their fields and consider using resistant varieties when seeding alfalfa. Many alfalfa varieties with high-yield performance have resistance or moderate resistance to verticillium wilt.

Other diseases and insects are problems for alfalfa, and some varieties of alfalfa have particular resistance

to these problems. You should question your seed supplier about these attributes of the varieties being offered to you.

Red clover is the second most important hay and pasture legume in Illinois. Although it does not have the yield potential of alfalfa under good production conditions, red clover can persist in more acidic soils and under more shade competition than can alfalfa. And, although red clover is a perennial physiologically, root and crown diseases limit the life of red clover to 2 years. Many new varieties have an increased resistance to root and crown diseases and are expected to be productive for at least 3 years. (See Table 30.)

Red clover does not have as much seedling vigor or as rapid a seedling growth rate as alfalfa. Therefore, red clover does not fit into a spring seeding program without a companion crop as well as does alfalfa.

Red clover has more shade tolerance at the seedling stage than alfalfa does; therefore, red clover is recommended for most pasture renovation mixtures where shading by existing grasses occurs. The shade tolerance of red clover enables it to establish well in companion crops such as spring oats and winter wheat.

There are fewer varieties of red clover than of alfalfa. Private breeders are active in developing more varieties of red clover.

Fewer acres are dedicated to mammoth red clover, because its yields have been lower than most of the improved varieties of medium red clover.

Ladino clover is an important legume in pastures, but it is a short-lived species. The very leafy nature of ladino makes it an excellent legume for swine. It is also a very high-quality forage for ruminant animals, but problems of bloat are frequent.

Ladino lacks drought tolerance because its root system is shallower than that of red clover or alfalfa.

Birdsfoot trefoil has been popular in permanent pastures in northern Illinois. It has a long life but becomes established very slowly. Seedling growth rate is much slower than that of alfalfa or red clover.

A root rot has made birdsfoot trefoil a short-lived crop throughout southern Illinois. The variety Dawn may have adequate resistance to persist throughout the state (see Table 31 for variety yields).

Rooting depth of birdsfoot trefoil is shallower than that of alfalfa, thus birdsfoot trefoil is not as productive during drought.

Crownvetch is well known for protecting very erosive soil areas. As a forage crop, crownvetch is much slower than alfalfa or red clover in seedling emergence, seedling growth rate, early-season growth, and recovery growth.Growth rate is similar to that of birdsfoot trefoil. The potential of crownvetch as a hay or pasture plant seems restricted to very rough sites and soils of low productivity.

Sainfoin is a legume that was introduced into the western United States from Russia. In Illinois tests, this species has failed to become established well enough to allow valid comparisons with alfalfa, red clover, and others. Observations indicate that sainfoin has a slow growth and recovery growth rate and is not well suited to the humid conditions in Illinois.

Hairy vetch is a winter annual legume that has limited value as a hay or pasture species. Low production and its vinelike nature have discouraged much use. Hairy vetch may reseed itself and become a weedy species in small grain fields. Hairy vetch seeded with winter wheat at 22 to 25 pounds per acre has increased the protein yield of wheat-vetch silage.

Lespedeza is a popular annual legume in the southern third of Illinois. It flourishes in midsummer when most other forage plants are at low levels of productivity. It survives on soils of low productivity and is low yielding. Even in midsummer, it does not produce as well as a good stand of alfalfa, nor will it encroach on a good alfalfa stand. As alfalfa or other vigorous pasture plants fade out of a pasture, lespedeza may enter.

Inoculation

Legumes — such as alfalfa, red clover, crownvetch, hairy vetch, ladino, and birdsfoot trefoil — can meet their nitrogen needs from the soil atmosphere if the roots of the legume have the correct Rhizobium species and favorable conditions of soil pH, drainage, and temperature. Rhizobium bacteria are numerous in most

Table 30. Resistance Levels of Red Clover Varieties

Variety	Anthracnose resistance[a]		Powdery mildew resistance
	Northern	Southern	
Arlington	R	...	R
E688	T	R	R
Flare	MR	R	R
Florex	R	...	MR
Florie	R	R	R
Mega	R	R	R
MorRed	HR	MR	HR
Reddy	MR	MR	?
Redland	MR	R	R
Redland II	R	R	R
Redman	R	MR	R
Ruby	R	R	?

[a] R = resistant; T = tolerant; MR = moderately resistant; HR = highly resistant.

Table 31. Birdsfoot Trefoil Variety Yields, 1987

Variety	Amount of dry matter			
	DeKalb	Urbana	Monmouth	Brownstown
	tons per acre			
Carroll	2.27	6.05	1.85	1.21
Dawn	2.09	6.67	1.64	1.44
Empire	2.02	6.41	1.71	1.11
Fergus	...	...	...	...
Leo	1.95	5.92	1.52	1.11
Mackinaw	2.19	6.51	1.80	...
Maitland	2.07	6.63	1.55	1.04
Norcen	1.88	6.84	1.74	1.07
Viking	2.05	6.20	1.37	1.51

soils; however, the species needed by a particular legume species may be lacking.

There are seven general groups and some other specific strains of Rhizobium, with each group specifically infecting roots of plants within its corresponding legume group and some specific strains infecting only a single legume species. The legume groups are (1) alfalfa and sweet clover; (2) true clovers (such as red, ladino, white, and alsike); (3) peas and vetch (such as field pea, garden pea, and hairy vetch); (4) beans (such as garden and pinto); (5) cowpeas and lespedeza; (6) soybeans; and (7) lupines. Some of the individual Rhizobium strains are specific to (1) birdsfoot trefoil; (2) crownvetch; or (3) sainfoin.

Grasses

Cool-season perennials

Timothy is the most popular hay and pasture grass in Illinois, although it is not as high yielding and has less midsummer production than smooth bromegrass. It is a cool-season species, best suited to the northern half of Illinois. There are promising new varieties (Table 32).

Smooth bromegrass is probably the most widely adapted high-yielding grass species for northern and central Illinois. Smooth bromegrass combines well with alfalfa or red clover. It is productive but has limited summer production when moisture is lacking and temperatures are high. It produces well in spring and fall and can utilize high-fertility programs. There are a few improved varieties, and breeding work continues (Table 33).

Orchardgrass is one of the most valuable grasses used for hay and pasture in Illinois. It is adapted throughout the state, being marginally winter hardy for the northern quarter of the state. Orchardgrass heads out relatively early in the spring and thus should be combined with alfalfa varieties that flower early. One of the more productive grasses in midsummer, it is a high-yielding species and several varieties are available (Table 34).

Reed canarygrass is not widely used, but it has growth attributes that deserve consideration. Reed canarygrass is the most productive of the tall, cool-season perennial grasses that are well suited to Illinois hay and pasture lands. It tolerates wet soils but also is one of the most drought-resistant grasses and can utilize high fertility. It is coarser than orchardgrass or bromegrass but not as coarse as tall fescue. Grazing studies indicate that, under proper grazing management, reed canarygrass can produce good weight gains on cattle equal to those produced by bromegrass, orchardgrass, or tall fescue. Reed canarygrass should be considered for grazing during spring, summer, and early fall. Cool temperatures and frost retard growth and induce dormancy earlier than with tall fescue, smooth bromegrass, or orchardgrass. New low-alkaloid varieties have improved animal performance (Table 35).

Tall fescue is a high-yielding grass (Table 36). It is outstanding in performance when used properly and is a popular grass for beef cattle in southern Illinois. Because it grows well in cool weather, tall fescue is especially useful for winter pasture; and it is also most palatable during the cool seasons of spring and late fall. A fungus living within the plant tissue (endophyte) has a major influence on the lower palatability and

Table 32. Timothy Variety Yields, 1985-87

Variety	Amount of dry matter		
	DeKalb	Urbana	Perry
	tons per acre		
Mariposa	2.31	4.98	2.60
Mohawk	2.08	5.03	3.00
Richmond	2.27	4.78	2.46

Table 33. Smooth Bromegrass Variety Yields, 1985-87

Variety	Amount of dry matter		
	DeKalb	Urbana	Perry
	tons per acre		
Blair	1.88	...	2.53
Bravo	2.11	5.01	2.27
FS Beacon	2.46	5.15	2.54
Jubilee	1.99	5.21	2.04

Table 34. Orchardgrass Variety Yields, 1985-87

Variety	Amount of dry matter		
	DeKalb	Urbana	Perry
	tons per acre		
Crown	2.22	5.50	2.38
Dart	2.38	5.40	2.63
Hallmark	2.17	5.06	2.27
Hawk	2.18	5.32	2.55
Ina	2.35	5.63	2.67
Juno	2.20	4.81	2.44
Potomac	1.89	4.81	2.27
Rancho	2.12	5.25	3.02

Table 35. Reed Canarygrass, Kentucky Bluegrass, Perennial Ryegrass Variety Yields, 1985-87

Variety	Amount of dry matter		
	DeKalb	Urbana	Perry
	tons per acre		
Kentucky bluegrass			
Dormie	1.55	3.62	2.41
Perennial ryegrass			
Grimalda	2.00	2.40	1.30
Reed canarygrass			
Palaton	2.49	5.59	3.24
Venture	2.35	5.67	3.10

Table 36. Tall Fescue Variety Yields, 1985-87

Variety	Amount of dry matter		
	DeKalb	Urbana	Perry
	tons per acre		
Forager	2.53	5.43	2.61
Johnstone	2.65	5.83	2.75
Kenhy	2.35	5.77	2.72
Mustang	2.17	5.21	2.51

digestibility of this grass during the warm summer months. Varieties are available that are fungus-free or low in fungus. Forager, Johnstone, and Kenhy are productive varieties in Illinois that are low in endophyte fungus. Tall fescue is marginally winter hardy when used in pastures or hay crops in the northern quarter of the state.

Warm-season annuals

Sudangrass, sudangrass hybrids, and sorghum-sudangrass hybrids are annual grasses that are very productive in late summer. These grasses must be seeded each year on a prepared seedbed. Although the total-season production from these grasses may be less than that from perennial grasses with equal fertility and management, these annual grasses fill a need for quick, supplemental pastures or green feed. These tall, juicy grasses are difficult to make into high-quality hay. Sudangrass and sudangrass hybrids have finer stems than the sorghum-sudan hybrids and thus will dry more rapidly; they should be chosen for hay over the sorghum-sudan hybrids. Crushing the stems with a hay conditioner will help speed drying.

Sudangrass, sudangrass hybrids, and sorghum-sudangrass hybrids produce prussic acid, a compound that is toxic to livestock. Prussic acid is the common name for hydrogen cyanide (HCN). The compound in sorghum plants that produces HCN is dhurrin. Two enzymes are required to hydrolyze dhurrin to HCN. The microflora in the rumen of ruminant animals are capable of enzymatic breakdown of dhurrin. The concentration of dhurrin is highest in young tissue, with more found in leaves than in stems. There is more dhurrin in grain or forage sorghums than in sorghum-sudangrass hybrids, and more in sorghum-sudangrass hybrids than in sudangrass hybrids or sudangrass.

Sudangrass and sudangrass hybrids are considered safe for grazing when they are 18 inches tall. The sorghum-sudangrass hybrids should be 24 inches tall before grazing is permitted. Very hungry cattle or sheep should be fed other feeds that are low in prussic acid potential before turning them onto a lush sudangrass or sorghum-sudangrass pasture. This pre-feeding will prevent rapid grazing and a sudden influx of forage that contains prussic acid. These animals can tolerate low levels of prussic acid because they can metabolize and excrete the HCN.

Frost on the crops of the sorghum family causes the plant enzymes to come into contact with dhurrin and HCN to be released rapidly. For this reason, it is advisable to remove grazing ruminant livestock from freshly frosted sudangrasses and sorghums. When the frosted plant material is thoroughly dry, usually after 3 to 5 days, grazing can resume. Grazing after this time should be observed closely for new tiller growth, which will be high in dhurrin; and livestock should be removed when there is new tiller growth.

The sorghums can be ensiled. The fermentation of ensiling reduces the prussic acid potential very substantially. This method is the safest for using feed that has a questionably high prussic acid potential.

Harvesting these crops as hay is also a safe way of using a crop with questionably high levels of prussic acid potential.

Toxic levels of prussic acid (HCN) vary. Some workers report toxicity at 200 ppm HCN of tissue dry weight, while others report moderate toxicity at 500 to 750 ppm HCN of tissue dry weight. Laboratory diagnostic procedures can determine relative HCN potential. An alkaline picrate solution is commonly used to detect HCN in plant tissue.

Millets are warm-season annual grasses that are drought tolerant. Four commonly known millets are pearlmillet (*Pennisetum typhoides*), browntop millet (*Panicum ramosum*), foxtail or Italian millet (*Setaria italica*), and Japanese millet (*Echinochloa crusgalli*). Pearlmillet has been evaluated in grazing trials and is a suitable alternative for summer annual pastures.

Pearlmillet requires a warmer soil for rapid establishment than does sudangrass. Seedings should be delayed until the soil temperature in the seedbed averages 70°F.

Pearlmillet does not have a prussic acid potential as does sudangrass, nor is pearlmillet as susceptible to leaf diseases. Pearlmillet is more drought tolerant than is sudangrass, thus producing more pasture during the hot, dry periods of late summer.

Forage mixtures

Mixtures (Table 38) of legumes and grasses usually are desirable. Yields tend to be greater than with either the legume or the grass alone. Grasses are desirable additions to legume seedings to fill in where the legume ceases to grow, to reduce soil erosion, to increase the drying rate, and perhaps to improve animal acceptance. Mixtures of two or three well chosen species are usually higher yielding than mixtures that contain five or six species, some of which are not particularly well suited to the soil, climate, or use.

Warm-season perennials

Warm-season perennial grasses also are known as native prairie grasses. These prairie grasses normally provide ample quantities of good- to high-quality pasture during midsummer when cool-season perennials are low yielding and perhaps of low quality.

Table 37. Hay, Pasture, and Silage Crop Varieties

Crop	Variety	Origin	Use
Ladino clover	Merit	Iowa	Pasture
Birdsfoot trefoil	Carroll	Iowa	Hay and pasture
	Dawn	Missouri	Pasture
	Empire	New York	Pasture
	Fargo	North Dakota	Hay and pasture
	Fergus	Kentucky	Hay and pasture
	Leo	Canada	Hay and pasture
	Mackinaw	Michigan	Hay and pasture
	Maitland	Europe	Hay and pasture
	Norcen	North Central States	Hay and pasture
	Viking	New York	Hay and pasture
Crownvetch	Chemung	New York	Erosion and pasture
	Emerald	Iowa	Erosion and pasture
	Penngift	Pennsylvania	Erosion and pasture
Smooth bromegrass	Barton	Land O'Lakes, Inc.	Hay and pasture
	Baylor	AgriPro	Hay and pasture
	Blair	AgriPro	Hay and pasture
	Bravo	Otto Pick & Sons Seed, Inc.	Hay and pasture
	FS Beacon	Land O'Lakes, Inc.	Hay and pasture
	Jubilee	Otto Pick & Sons Seed, Inc.	Hay and pasture
	Lincoln	University of Nebraska	Hay and pasture
	Sac	University of Wisconsin	Hay and pasture
Orchardgrass	Benchmark	Farm Forage Research Cooperative	Hay and pasture
	Boone	Kentucky	Hay and pasture
	Crown	AgriPro	Hay and pasture
	Dart	Land O'Lakes, Inc.	Hay and pasture
	Dayton	AgriPro	Hay and pasture
	Hawk	AgriPro	Hay and pasture
	Ina	Northrup, King and Co.	Hay and pasture
	Juno	Ottawa Research Station	Hay and pasture
	Napier	AgriPro	Hay and pasture
	Pennlate	Pennsylvania	Hay and pasture
	Potomac	Maryland	Hay and pasture
	Rancho	Farm Forage Research Cooperative	Hay and pasture
	Sterling	Iowa	Hay and pasture
Tall fescue	Alta	Oregon	Pasture
	Fawn	Oregon	Pasture
	Forager	Farm Forage Research Cooperative	Pasture (low endophyte fungus)
	Kenhy	Kentucky	Pasture (more palatable, low endophyte fungus)
	Kenwell	Kentucky	Pasture (more palatable)
	Ky-31	Kentucky	Pasture
	Martin	Missouri	Pasture (higher magnesium; low endophyte fungus)
	Mozark	Missouri	Pasture (low endophyte fungus)
	Mustang	Rutgers University	Pasture
	Johnstone	Kentucky	Pasture (low endophyte fungus)
Timothy	Clair	Kentucky	Hay
	Climax	Indiana	Hay
	Itasca	Minnesota	Hay
	Mariposa	Otto Pick & Sons Seed, Inc.	Hay
	Mohawk	Farm Forage Research Cooperative	Hay
	Pronto	Pride Company, Inc.	Hay
	Richmond	Otto Pick & Sons Seed, Inc.	Hay
	Timfor	Northrup, King and Company	Hay
	Toro	AgriPro	Hay
	Verdant	Wisconsin	Hay

Switchgrasses, big bluestem, and indiangrass have been the more popular prairie grasses for use in Illinois.

Switchgrass (*Panicum virgatum L.*) is a tall, coarse-stemmed grass with long, broad leaves that grows 3 to 5 feet tall, with short rhizomes. It is not as palatable as smooth bromegrass. It is native to the Great Plains states.

In Illinois, switchgrass starts growing in May but makes most of its growth in June to August. Switchgrass is one of the earliest maturing prairie grasses. Grazing or harvesting should leave a minimum of a 4- to 6-inch stubble. Close grazing or harvesting quickly diminishes the stand.

Switchgrass needs abundant moisture and fertility for maximum growth. Because switchgrass is tolerant of moist soils, it is often used in grass waterways.

Varieties. Blackwell, Caddo, Kanlow, Nebraska 28, Pathfinder, and Trailblazer were selected in the Southern and Central Great Plains. Trailblazer, released in 1985, is more digestible than the other varieties. Cave-

Table 38. Forage Seed Mixture Recommendations, All Entries Given in Pounds per Acre

For hay crops

Central, Northern Illinois		Central, Southern Illinois	
Moderately to well-drained soils			
Alfalfa	12	Alfalfa Orchardgrass	8 4
Alfalfa Bromegrass	8 6	Alfalfa Tall fescue	8 6
Alfalfa Bromegrass Timothy	8 4 2		
Alfalfa Timothy	8 4		
Poorly drained soils			
Red clover Timothy	8 4	Red clover Bromegrass	8 6
Red clover Bromegrass	8 6		
Alsike clover Timothy	5 4	Reed canarygrass Alsike clover	8 4
Reed canarygrass Alsike clover	8 3	Tall fescue Alsike clover	6 4
Birdsfoot trefoil Timothy	5 2	Redtop Alsike clover	4 4
Droughty soils			
Alfalfa Bromegrass	8 6	Alfalfa Orchardgrass	8 4
Alfalfa Tall fescue[a]	8 6	Alfalfa Tall fescue	8 6
		Alfalfa Bromegrass	8 6

For horse pastures

Central, Northern Illinois		Southern Illinois	
Moderately to well-drained soils			
Alfalfa Smooth bromegrass Kentucky bluegrass	8 6 2	Alfalfa Orchardgrass Kentucky bluegrass	8 3 5
Poorly drained soils			
Ladino clover Smooth bromegrass Kentucky bluegrass Timothy	½ 6 2 2	Ladino clover Orchardgrass Kentucky bluegrass	½ 6 5

Central Illinois

Central Illinois	
Moderately to well-drained soils	
Alfalfa Orchardgrass Kentucky bluegrass	8 3 2
Poorly drained soils	
Ladino clover Orchardgrass Kentucky bluegrass	½ 6 2

For hog pastures

All soil types, anywhere in Illinois	
Alfalfa Ladino clover	8 2

For rotation and permanent pastures

Central, Northern Illinois		Southern Illinois	
Moderately to well-drained soils			
Alfalfa Bromegrass Timothy	8 5 2	Alfalfa Orchardgrass	8 4
Alfalfa Orchardgrass[a]	8 4	Alfalfa Tall fescue	8 6
Alfalfa Orchardgrass[a] Timothy	8 4 2	Tall fescue Ladino clover	8 ½
Orchardgrass[a] Ladino clover	6 ½	Alfalfa Bromegrass Timothy	8 6 2
Red clover Ladino clover Orchardgrass[a]	8 ½ 4	Orchardgrass Ladino clover	6 ½
Red clover Ladino clover Tall fescue	8 ½ 6-8	Tall fescue	10
Birdsfoot trefoil Timothy	5 2	Orchardgrass	8
Ladino clover Bromegrass	½ 8	Red clover Ladino clover Orchardgrass	8 ½ 4
Tall fescue	10	Red clover Ladino clover Tall fescue	8 ½ 6-8
Orchardgrass[a]	8		
Poorly drained soils			
Alsike clover Ladino clover Timothy	3 ¼ 4	Alsike clover Ladino clover Tall fescue	2 ½ 8
Birdsfoot trefoil Timothy	5 2	Alsike clover Ladino clover Reed canarygrass	3 ½ 8
Reed canarygrass Alsike clover Ladino clover	8 3 ¼-½		
Alsike clover Ladino clover Tall fescue	2 ½ 8		
Droughty soils			
Alfalfa Bromegrass	8 5	Alfalfa Orchardgrass	8 4
Alfalfa Orchardgrass[a]	8 4	Alfalfa Tall fescue	8 6
Alfalfa Tall fescue	8 6	Red clover Ladino clover Orchardgrass[a]	8 ½ 4
Red clover Ladino clover Orchardgrass	8 ½ 4	Red clover Ladino clover Tall fescue	8 ½ 6-8
Red clover Ladino clover Tall fescue	8 ½ 6-8		

For pasture renovation

Central, Northern Illinois		Southern Illinois	
Moderately to well-drained soils			
Alfalfa Red clover	8 4	Alfalfa Red clover	8 4
Poorly drained soils			
Birdsfoot trefoil Red clover	4 4	Alsike Ladino clover Red clover	2 ½ 4

[a] Central Illinois only.

in-Rock was selected from southern Illinois in 1958 and released by the Soil Conservation Service, Elsberry, Missouri, in 1972. Cave-in-Rock has yielded well in Illinois trials.

Switchgrass should be seeded in mid-April to early May. A continuous supply of soil moisture is needed for germination and early seedling develoment. Precipitation during the first 10 days following seeding has beeen more important for the establishment of switchgrass than the seeding date.

A seeding rate of 6 pounds of pure live seed (PLS) per acre of switchgrass is adequate if weeds are controlled and precipitation is favorable. Increasing the seeding rate increases the number of seedlings established but has little effect on forage yield or forage quality of established stands.

Frequent grazing or hay harvesting — more often than every 6 weeks — reduces the yield and vigor of switchgrass. A harvest may be taken after frost without reducing yield and vigor the following year.

Crude protein and digestible dry matter of switchgrass decline with maturity. Animal gains on switchgrass may be less than on big bluestem or indiangrass.

Switchgrass, indiangrass, and big bluestem yield well as pasture plants. A major portion of the growth occurs before July 1, and nearly all growth from these grasses is completed by August 1 in Southern Illinois. The dry matter yield of switchgrass is greater than that of indiangrass and big bluestem.

The crude protein content of switchgrass is higher than indiangrass or big bluestem at the same dates during the pasture season. The crude protein values range from 3.4 to 6.4 percent for the major yield of the season. These values are very low if these forages are the only protein source for cattle, sheep, or horses. Big bluestem tends to have a higher crude protein content than indiangrass.

The digestible dry matter of warm-season perennial grasses tends to be below 50 percent, which is below the maintenance level for pregnant beef cows. Pregnant beef cows may need supplemental feed when pasturing on switchgrass. Indiangrass and big bluestem tend to be a little higher in digestibility than switchgrass, but they are marginal for maintenance of pregnant beef cows. Dry-matter digestibility may be underestimated by *in vitro* analysis methods.

Warm-season perennial grasses may yield 5.5 to 7.5 tons of hay dry matter per acre throughout Illinois.

Big bluestem (*Andropogon gerardii*) grows to 4 to 7 feet tall and is a sod-forming, warm-season perennial grass. It was a major contributor to the development of the deep, dark, prairie soils of Illinois. This perennial has short rhizomes, but it makes a very tough sod. Big bluestem thrives on moist, well-drained loam soils of relatively high fertility. It is one of the dominant grasses of the Eastern Great Plains and is found in association with little bluestem, switchgrass, and indiangrass. Big bluestem establishes slowly from seed.

Big bluestem begins growth in May and makes a large part of its growth in late July through August. Grazing should leave a 6-inch stubble to prevent loss of stand.

This grass is palatable and nutritious in its early stages of growth. It withstands close grazing late in the season if it is protected from close grazing early in the season. Good hay may be made if harvested before seed heads emerge. Seed matures in late September and October.

Roundtree big bluestem was released by the Soil Conservation Service and the Missouri Agricultural Experiment Station in 1983. Other varieties of big bluestem are Champ, Kaw, and Pawnee. Other bluestem varieties include Plains (Yellow Bluestem), released by the Oklahoma Agricultural Experiment Station in 1970; King Ranch; and Caucasian.

Indiangrass (*Sorghastrum nutans*) is a sod-forming grass with a deep, extensive root system with short rhizomes. It is adapted to deep soils that are not extremely wet.

Indiangrass produces fair- to good-quality forage during the summer months. Grazing months are July through mid-September. Harvest indiangrass for hay at the early boot stage. Begin grazing after the plant reaches 18 inches in height. Graze to a minimum of a 10-inch stubble.

Varieties are Holt, from the Nebraska Agricultural Experiment Station; Osage, from the Kansas Agricultural Experiment Station; Oto, from the Nebraska Agricultural Experiment Station; and Rumsey, from a native stand in south central Illinois.

Seedings should be made from mid-May to mid-June at 10 to 12 pounds of pure live seed (PLS) per acre. Seed at one-fourth inch deep, on a prepared seedbed that has been firmed with a corrugated roller. Use no nitrogen during the seeding year.

Establishment of warm-season perennial grasses

Establishment of warm-season perennial grasses is slow. Seedings need to be made early in the season, from April through June, to allow adequate time for the seedlings to become well established. Atrazine (at 2 pounds of active ingredients per acre) may be applied to the surface after seeding big bluestem. Switchgrass and indiangrass seedlings are damaged by atrazine.

Seeding rates of 5 to 6 pound PLS per acre of switchgrass and 10 to 12 pounds of PLS per acre of big bluestem and indiangrass are suggested rates. Do not graze until the plants are well established, at least one year old. Weeds may be reduced during the seeding year by clipping. The first clipping should be done at about 60 days after seeding and at a height of 3 inches. Later clippings should be at no less than 6-inch stubble height. Do not clip after August 1.

Seedings should be made on prepared seedbeds that are very firm. The drill or seeder must be able to handle the seed, because seeds of indiangrass and big bluestem are light and feathery. Debearding will help to get the seed through the seeders.

Seedings may be made into existing grass sods, but the grass must be destroyed. Roundup will remove most grasses when applied according to label instructions. Atrazine also may be used when seeding big bluestem. A no-till drill is needed to place seeds into the soil surface and to obtain a good soil-seed contact.

Fertilization

Warm-season perennial grasses prefer fertile soils but grow well in moderate fertility conditions. Warm-season perennials do not respond to nitrogen fertilization as much as cool-season perennials. Warm-season perennial grasses are more efficient in the use of minerals and moisture than are cool-season perennial grasses.

For establishment, fertilize with 30 to 40 pounds of nitrogen, 24 to 30 pounds of phosphate, and 40 to 60 pounds of potash per acre.

For pasture or hay production of established stands, fertilize with 100 to 120 pounds of nitrogen, 50 to 60 pounds of phosphate, and 100 to 120 pounds of potash per acre.

Pollination of legume seeds

Illinois is an important producer of red clover seed. Yields vary widely from year to year, with warm, dry summers favoring seed production. In part, low yields are caused by inadequate pollination by bees. Only during the clover's second growth period do honey bees visit red clover in numbers high enough to pollinate it while they collect pollen and nectar. In experiments on the Agronomy Farm at Urbana, honey bees collected 54 to 99 percent of their daily pollen intake from red clover between July 12 and August 3.

Bumblebees also pollinate red clover, but they cannot be relied upon because they are not always present and their numbers are unpredictable. The presence of honey bees in the vicinity of red clover fields cannot be assured — because of insufficient numbers of hives in Illinois.

To produce red clover seed, use the second growth period crop and at least two colonies of honey bees per acre within or beside the field. On large fields, place the hives in two or more groups. Do not rely on bees present in the neighborhood, because pollination and seed set decrease rapidly as distance between the hives and the crop becomes greater than 800 feet. Bring a sufficient number of hives to the field as soon as it comes into bloom. When all factors for seed production are favorable, proper pollination of red clover by honey bees has the potential of doubling or tripling seed yields.

White and yellow sweet clovers are highly attractive to bees and other insects. Still, probably because of the large number of blossoms, their seed yields increase when colonies of honey bees are placed nearby. Yields up to 1,400 pounds per acre have been produced in the Midwest when using six colonies of bees per acre. One or two hives per acre will give reasonably good pollination.

Crownvetch does not attract bees and requires special techniques to produce a commercial crop of seed. Best yields have been obtained by bringing strong, new hives of bees to the fields every 8 to 10 days. Instead of such special provisions, one or more hives of honey bees per acre of crownvetch are of value.

The effects of insect pollination on annual lespedeza, such as Korean, have not been investigated; but the perennial lespedezas require insect pollination to produce a crop of seed, and honey bees can be used.

Many legumes grown in Illinois for pasture or for purposes other than seed production are visited by honey bees and other bee pollinators. Alfalfa and birdsfoot trefoil — as well as alsike, white, and ladino clovers — all provide some pollen and nectar and, in turn, are pollinated to varying degrees.

During their bloom in July and August, soybeans at Urbana are visited by honeybees. The beans are a major source of honey in the state. In tests at Urbana, honey bee visits to soybeans did not increase seed yield over that of plants caged to exclude bees. Other studies have indicated that some varieties increase yields as a result of increasing honey bee visits during flowering.

Soil Testing and Fertility

Soil testing

Soil testing is the most important single guide to the profitable application of fertilizer and lime. When soil test results are combined with information about the nutrients that are available to the various crops from the soil profile, the farmer has a reliable basis for planning the fertility program on each field.

Traditionally, soil testing has been used to decide how much lime and fertilizer to apply. Today, with increased emphasis on the environment, soil tests are also a logical tool to determine areas where adequate or excessive fertilization has taken place.

How to sample. A soil tube is the best implement to use for taking soil samples, but a spade or auger also can be used (Figure 4). One composite sample from every 3 to 4 acres is suggested. Five soil cores taken with a tube will give a satisfactory composite sample of about 1 to 2 cups in size. You may follow a regular pattern as indicated in Figure 5.

The most common mistake is taking too few samples to represent the fields adequately. Taking shortcuts in sampling may produce unreliable results and lead to higher fertilizer costs, lower returns, or both.

It is important to collect soil samples to the proper depth — 7 inches. For fields in which reduced tillage systems have been used, proper sampling depth is especially important, as these systems result in less thorough mixing of lime and fertilizer than does a tillage system that includes a moldboard plow. This stratification of nutrients has not adversely affected crop yields, but misleading soil test results may be obtained if samples are not taken to the proper depth.

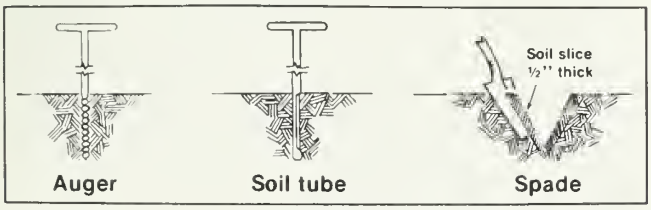


Figure 4. How to take soil samples with an auger, soil tube, and spade.

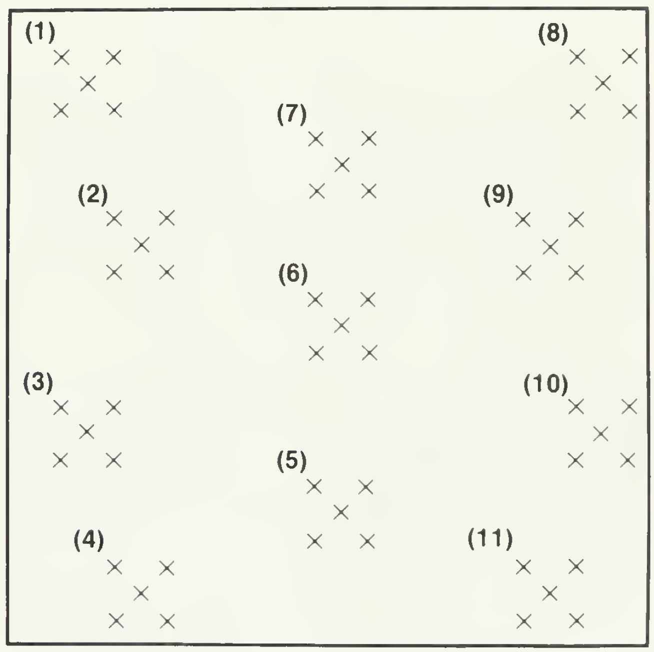


Figure 5. Soil-sampling patterns for a 40-acre field. For a 20-acre field, eliminate 8 through 11.

When to sample. Sampling every 4 years is strongly suggested. Late summer and fall are the best seasons for collecting soil samples from the field because potassium test results are most reliable during these

times. Sampling frozen soil or within 2 weeks after the soil has thawed should be avoided.

Where to have soil tested. Illinois has about 65 commercial soil-testing services. Your county Extension adviser or fertilizer dealer can advise you about availability of soil testing in your area.

Information to accompany soil samples. The best fertilizer recommendations are those based on both soil test results and a knowledge of the field conditions that will affect nutrient availability. Because the person making the recommendation does not know the conditions in each field, it is important that you provide adequate information with each sample.

This information includes cropping intentions for the next 4 years; the nature of the soil (clay, silty, or sandy; light or dark color; level or hilly; eroded; well drained or wet; tiled or not; deep or shallow); fertilizer used (amount and grade); if the field was limed in the past 2 years; and yield goals for all proposed crops.

What tests to have made. Soil fertility problems in Illinois are largely associated with acidity, phosphorus, potassium, and nitrogen. Useful and recommended soil tests for making decisions about lime and fertilizer use are as follows: water pH test, which will show soil reation as pH units; Bray P_1 test for plant-available soil phosphorus, which will commonly be reported as pounds of phosphorus per acre (elemental basis); and the potassium (K) test which will commonly be reported as pounds of potassium per acre (elemental basis). Guides for interpreting these tests are included in this section. An organic-matter test made by some laboratories is particularly useful in selecting the proper rate of herbicide and agricultural limestone.

Because nitrogen (N) can change forms or be lost from the soil, the use of soil testing to determine nitrogen fertilizer needs for Illinois field crops is not recommended in the same sense that soil testing is used for determining the need for lime, phosphorus, and potassium fertilizer. Use of the organic-matter test as a nitrogen soil test may be misleading and result in underfertilization. Guides for planning nitrogen fertilizer use are provided later in this section.

Tests are available for most of the secondary nutrients and micronutrients, but interpretation of these tests is less reliable than the interpretation of tests for lime, phosphorus, or potassium. Complete field history and soil information are especially important in interpreting the results. Even though these tests are less reliable, they may be useful in two ways:

1. *Trouble shooting.* Diagnosing symptoms of abnormal growth. Paired samples representing areas of good and poor growth are needed for analyses.
2. *"Hidden-hunger checkup."* Identifying deficiencies before symptoms appear. Soil tests are of little value in indicating marginal levels of secondary nutrients and micronutrients when crop growth is apparently normal. For this purpose, plant analysis may yield more information.

The rating of soil tests (given in Table 39) has been developed to put into perspective the reliability, usefulness, and cost effectiveness of soil tests as a basis for planning a soil fertility and liming program for field crops in Illinois. These subjective ratings are on a scale from 0 to 100, for which a score of 100 is deemed very reliable, useful, and cost effective and a score of zero is deemed of little value. Additional research will undoubtedly improve some test ratings.

Plant analysis

Plant analyses can be useful in diagnosing problems, in identifying hidden hunger, and in determining whether current fertility programs are adequate. They often provide more reliable measures of micronutrient and secondary nutrient problems than do soil tests.

How to sample. When making a plant analysis to diagnose a problem, select paired samples of comparable plant parts representing the abnormal and normal plants. Abnormal plants selected should represent the first stages of a problem.

When using the technique to diagnose hidden hunger, for corn, sample several of the leaves opposite and below the ear at early tassel time. For soybeans, sample the most recent fully developed leaves and petioles at early podding. Samples taken later will not indicate the nutritional status of the plant. After you collect the samples, deliver them immediately to the laboratory. They should be air dried if they cannot be delivered immediately or if they are going to be shipped to a laboratory.

Environmental factors may complicate the interpretation of plant analysis data. The more information one has concerning a particular field, the more reliable the interpretation will be. Suggested critical nutrient levels are provided in Table 40. Lower levels may indicate a nutrient deficiency.

Lime

Soil acidity is one of the most serious limitations to crop production. Acidity is created by a removal of bases by harvested crops, leaching, and an acid residual that is left in the soil from nitrogen fertilizers. Over the last several years, limestone use has tended to decrease while crop yields and nitrogen fertilizer use have increased markedly (Figure 6).

At the present rate of limestone use, no lime is being added to correct the acidity that is created by the removal of bases nor the acidity created in prior years, which had not been corrected. A soil test every 4 years is the best way to check on soil acidity levels.

The effect of soil acidity on plant growth. Soil acidity affects plant growth in several ways. Whenever soil pH is low (that is, acidity is high), several situations may exist.

1. The concentration of soluble metals may be toxic. Damage from excess solubility of aluminum and

Table 39. Ratings of Soil Tests[a]

Soil test	Rating	Soil test	Rating
Water pH	100	Organic matter	75
Salt pH	30	Calcium	40
Buffer pH	30	Magnesium	40
Exchangeable H	10	Cation-exchange capacity	60
Phosphorus	85	Sulfur	40
Potassium	80	Zinc	45
Boron (alfalfa)	60	Manganese (pH = 7.5)	40
Boron (corn and soybeans)	10	Manganese (pH < 7.5)	10
Iron (pH > 7.5)	30	Copper (organic soils)	20
Iron (pH < 7.5)	10	Copper (mineral soils)	5

[a] On a scale of 0 to 100, for which a score of 100 rates the test as very reliable, useful, and cost effective and a score of zero rates the test as having little value.

Table 40. Suggested Critical Plant Nutrient Levels

Crop	Plant part	N	P	K	Ca	Mg	S	Zn	Fe	Mn	Cu	B
		percent						*ppm*				
Corn	Leaf opposite and below the ear at tasseling	2.9	0.25	1.90	0.40	0.15	0.15	15	25	15	5	10
Soybeans	Fully developed leaf and petiole at early podding	...	0.25	2.00	0.40	0.25	0.15	15	30	20	5	25

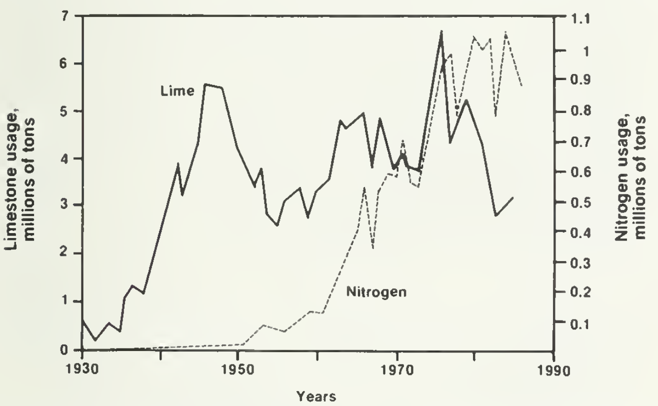


Figure 6. Use of agricultural lime and commercial nitrogen fertilizer, 1930-1986.

manganese due to soil acidity has been shown in field research.

2. Populations and the activity of the organisms responsible for transformations involving nitrogen, sulfur, and phosphorus may be altered.
3. Calcium may be deficient. This usually occurs only when the cation-exchange capacity of the soil is extremely low.
4. Symbiotic nitrogen fixation in legume crops is impaired greatly. The symbiotic relationship requires a narrower range of soil reaction than does the growth of plants not relying on nitrogen fixation.
5. Acidic soils are poorly aggregated and have poor tilth. This is particularly true for soils that are low in organic matter.
6. Availability of mineral elements to plants may be affected. Figure 7 shows the relationship between soil pH and nutrient availability. The wider the white bar, the greater the nutrient availability. For

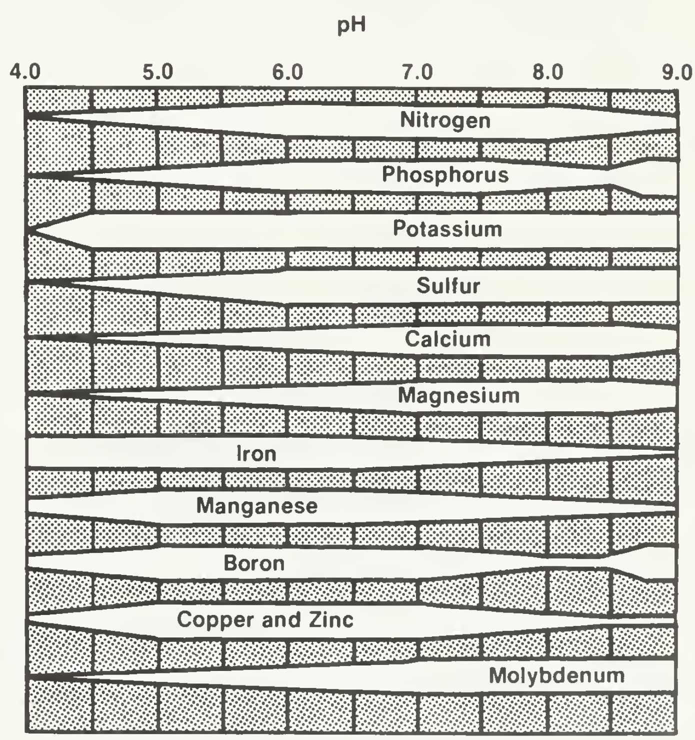


Figure 7. Available nutrients in relation to pH.

example, the availability of phosphorus is greatest in the pH range between 6.0 and 7.5, dropping off sharply below 6.0. Because the availability of molybdenum is increased greatly as soil acidity is decreased, molybdenum deficiencies can usually be corrected by liming.

Suggested pH goals. For cash-grain systems (no alfalfa or clover), maintaining a pH of at least 6.0 is a realistic goal. If the soil test shows that the pH is 6.0 or less, apply limestone. After the initial investment, it costs little more to maintain a pH at 6.5 than it does at 6.0. The profit over a 10-year period will be affected very little because the increased yield will about offset the cost of the extra limestone plus interest.

Research indicates that a profitable yield response from raising the pH above 6.5 in cash-grain systems is unlikely.

For cropping systems with alfalfa and clover, aim for a pH of 6.5 or higher unless the soils have a pH of 6.2 or higher without ever being limed. In those soils, neutral soil is just below plow depth; and it will probably not be necessary to apply limestone.

Liming treatments based on soil tests. The limestone requirements in Figure 8 assume:

1. A 9-inch plowing depth. If plowing is less than 9 inches deep, reduce the amount of limestone; if more than 9 inches, increase the lime rate proportionately. In zero-tillage systems, use a 3-inch depth for calculations.
2. Typical fineness of limestone. Ten percent of the particles are greater than 8-mesh; 30 percent pass an 8-mesh and are held on 30-mesh; 30 percent pass a 30-mesh and are held on 60-mesh; and 30 percent pass a 60-mesh.
3. A calcium carbonate equivalent (total neutralizing power) of 90 percent. The rate of application may be adjusted according to the deviation from 90.

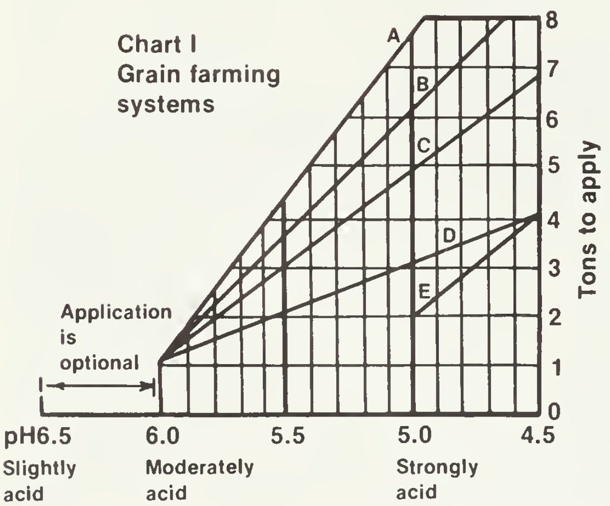
Instructions for using Figure 8 are as follows:

1. Use Chart I for grain systems and Chart II for alfalfa, clover, or lespedeza.
2. Decide which soil class fits your soil:
   a. Dark-colored silty clays and silty clay loams.
   b. Light- and medium-colored silty clays and silty clay loams; dark-colored silt and clay loams.
   c. Light- and medium-colored silt and clay loams; dark- and medium-colored loams; dark-colored sandy loams.
   d. Light-colored loams; light- and medium-colored sandy loams; sands.
   e. Muck and peat.

Soil color is related to organic-matter level. Light-colored soils usually have less than 2.5-percent organic matter; medium-colored soils have 2.5- to 4.5-percent organic matter; dark-colored soils have more than 4.5-percent organic matter; sands are excluded.

Limestone quality. Limestone quality is measured by the neutralizing value and the fineness of grind. The neutralizing value of limestone is measured by its calcium carbonate equivalent: the higher this value, the greater the limestone's ability to neutralize soil acidity. Rate of reaction is affected by particle size; the finer that limestone is ground, the faster it will neutralize soil acidity. Relative efficiency factors have been determined for various particle sizes (Table 41).

The quality of limestone is defined as its effective neutralizing value (ENV). This value can be calculated for any liming material by using the efficiency factors in Table 41 and the calcium carbonate equivalent for



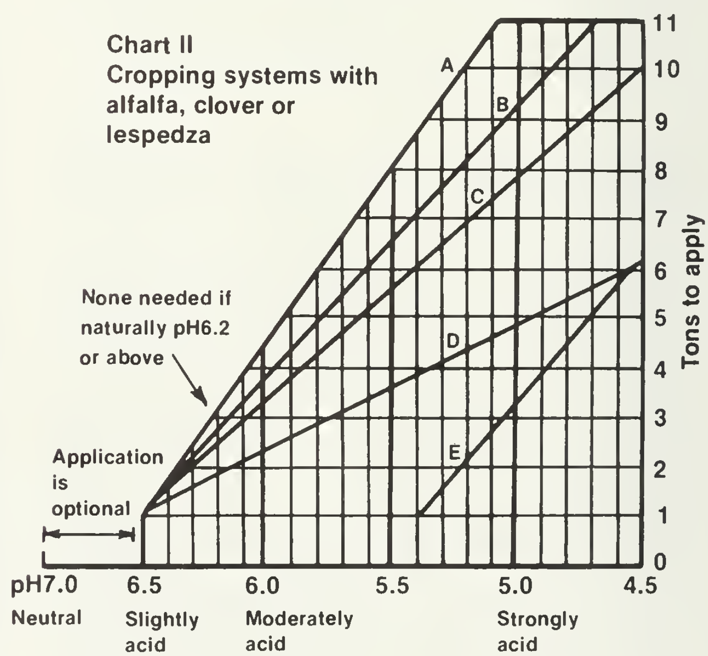


Figure 8. Suggested limestone rates based on soil type, pH, and cropping system.

Worksheet

Evaluation for 1 year after application

		Efficiency factor	
% of particles greater than 8-mesh	= $\frac{\_\_\_\_}{100}$ ×	5	=
% of particles that pass 8-mesh and are held on 30-mesh	= $\frac{\_\_\_\_}{100}$ ×	20	=
% of particles that pass 30-mesh and are held on 60-mesh	= $\frac{\_\_\_\_}{100}$ ×	50	=
% of particles that pass 60-mesh	= $\frac{\_\_\_\_}{100}$ ×	100	=
		Total fineness efficiency	____

ENV = total fineness efficiency $\times \frac{\text{\% calcium carbonate equivalent}}{100}$

$$\text{Correction factor} = \frac{\text{ENV of typical limestone (46.35)}}{\text{ENV of sampled limestone (\_\_\_\_)}}$$

Correction factor × limestone requirement (from Figure 8) = ____ tons of sampled limestone needed per acre

Evaluation for 4 years after application

		Efficiency factor	
% of particles greater than 8-mesh	= $\frac{\_\_\_\_}{100}$ ×	15	=
% of particles that pass 8-mesh and are held on 30-mesh	= $\frac{\_\_\_\_}{100}$ ×	45	=
% of particles that pass 30-mesh and are held on 60-mesh	= $\frac{\_\_\_\_}{100}$ ×	100	=
% of particles that pass 60-mesh	= $\frac{\_\_\_\_}{100}$ ×	100	=
		Total fineness efficiency	____

ENV = total fineness efficiency $\times \frac{\text{\% calcium carbonate equivalent}}{100}$

$$\text{Correction factor} = \frac{\text{ENV of typical limestone (67.5)}}{\text{ENV of sampled limestone (\_\_\_\_)}}$$

Correction factor × limestone requirement (from Figure 8) = ____ tons of sampled limestone needed per acre

Table 41. Efficiency Factors for Various Limestone Particle Sizes

Particle sizes	Efficiency factor	
	1 year after application	4 years after application
Greater than 8-mesh	5	15
8- to 30-mesh	20	45
30- to 60-mesh	50	100
Passing 60-mesh	100	100

the limestone in question. The "typical" limestone on which Figure 8 is based has an ENV of 46.35 for 1 year and 67.5 for 4 years.

The Illinois Department of Agriculture, in cooperation with the Illinois Department of Transportation, collects and analyzes limestone samples from quarries that wish to participate in the Illinois Voluntary Limestone Program. These analyses, along with the calculated correction factors, are available from the Illinois Department of Agriculture, Division of Plant Industries and Consumer Services, P.O. Box 19281, Springfield, Illinois 62794-9281, in an annual publication entitled *Illinois Voluntary Limestone Program Producer Information.* To calculate the ENV for materials not reported in that publication, obtain the analysis of the material in question from the supplier and use the worksheet on the following page.

As an example, consider a limestone that has a calcium carbonate equivalent of 86.88 percent, that the sample has 13.1 percent of the particles greater than 8-mesh, 40.4 percent that pass 8-mesh and are held on 30-mesh, 14.9 percent that pass 30-mesh and are held on 60-mesh, and 31.6 percent that pass 60-mesh. Assume that you need 3 tons of typical limestone per acre (according to Figure 8).

1 Year

$$\frac{13.1\%}{100} \times 5 = 0.65$$
$$\frac{40.4\%}{100} \times 20 = 8.08$$
$$\frac{14.9\%}{100} \times 50 = 7.45$$
$$\frac{31.6\%}{100} \times 100 = 31.60$$

Total fineness efficiency 47.78

$$\text{ENV} = 47.78 \times \frac{86.88}{100} = 41.51$$

$$\frac{46.35}{41.51} \times 3 = 3.35 \text{ tons per acre}$$

4 Years

$$\frac{13.1\%}{100} \times 15 = 1.96$$
$$\frac{40.4\%}{100} \times 45 = 18.18$$
$$\frac{14.9\%}{100} \times 100 = 14.90$$

$$\frac{31.6\%}{100} \times 100 = \underline{\underline{31.60}}$$

Total fineness efficiency 66.64

$$\text{ENV} = 66.64 \times \frac{86.88}{100} = 57.9$$

$$\frac{67.5}{57.9} \times 3 = 3.5 \text{ tons per acre}$$

At rates up to 6 tons per acre, if high initial cost is not a deterrent, you may apply the entire amount at one time. If cost is a factor and the amount of limestone needed is 6 tons or more per acre, apply it in split applications of about two-thirds the first time and the remainder 3 or 4 years later.

Fluid lime suspensions (liquid lime). These products are produced by suspending very finely ground limestone in water. In addition, several industrial by-products that have liming properties are being land-applied as suspensions, either because they are too fine to be spread dry or they are already in suspension. These by-product materials include residue from water treatment plants, cement plant stack dusts, paper mill sludge, and other waste products. These materials may contain as much as 50-percent water. In some cases, a small amount of attapulgite clay is added as a suspending agent.

The chemistry of liquid liming materials is the same as that of dry materials. Research results have confirmed that the rate of reaction and neutralizing power for liquid lime are the same as for dry materials when particle sizes are the same.

Results collected from one research study indicate that application of liquid lime at the rate of material calculated by the following equation is adequate to maintain soil pH for at least a 4-year period at the same level as typical lime.

$$\frac{\text{ENV of typical limestone (use 46.35)}}{\text{100 (fineness efficiency factor)} \times \dfrac{\text{\% calcium carbonate equivalent, dry matter basis}}{100} \times \dfrac{\text{\% dry matter}}{100}}$$

× tons of limestone needed per acre = tons of liquid lime needed per acre.

During the first few months after application, the liquid material will provide a more rapid increase in pH than will typical lime, but after that the two materials will provide equivalent pH levels in the soil.

As an example, assume a lime need of 3 tons per acre (based on Figure 8) and liquid lime that is 50-percent solid and has a calcium carbonate equivalent of 97 percent on a dry matter basis. The rate of liquid lime needed would be calculated as follows.

$$\frac{46.35}{100 \times \dfrac{97}{100} \times \dfrac{100\text{-}50}{100}} \times 3 = 2.87 \text{ tons of liquid lime per acre}$$

Lime incorporation. Lime does not react with acidic soil very far from the particle; but special tillage operations to mix lime with soil usually are not necessary in systems that use a moldboard plow. Systems of tillage that use a chisel plow, disk, or field cultivator rather than a moldboard plow, however, may not mix limestone deeper than 4 to 5 inches.

Calcium-magnesium balance in Illinois soils

Soils in northern Illinois usually contain more magnesium than those in central and southern Illinois because of the high magnesium content in the rock from which the soils developed and because northern soils are geologically younger. This relatively high level of magnesium has caused some speculation as to whether or not the level is too high. Although there have been reports of suggestions that either gypsum or low-magnesium limestone should be applied, no one has put forth research data to justify concern over a too-narrow ratio of calcium to magnesium.

On the other hand, concern is justified over a soil magnesium level that is low — because of its relationship with hypomagnesemia, a prime factor in grass tetany or milk fever in cattle. This concern is more relevant to forage production than to grain production. Very high potassium levels (more than 500 pounds per acre) combined with low soil magnesium levels contribute to low-magnesium grass forages. Research data to establish critical magnesium levels are very limited. However, levels of soil magnesium less than 60 pounds per acre on sands and 150 pounds per acre on silt loams are regarded as low.

Calcium and magnesium levels of agricultural limestone vary among quarries in the state. Dolomitic limestone (material with an appreciable magnesium content, as high as 21.7-percent MgO or 46.5-percent $MgCO_3$) occurs predominantly in the northern three tiers of Illinois counties, in Kankakee County, and in Calhoun County. Limestone occuring in the remainder of the state is dominantly calcitic (high calcium), although it is not uncommon for them to contain 1- to 3-percent $MgCO_3$.

For farmers following a grain system of farming, there are no agronomic reasons to recommend either that farmers in northern Illinois bypass local limestone sources, which are medium to high in magnesium, and pay a premium for low-magnesium limestone from southern Illinois or that farmers in southern Illinois order limestone from northern Illinois quarries because of magnesium content.

For farmers with a livestock program or who produce forages in the claypan and fragipan regions of the south, where soil magnesium levels may be marginal, it is appropriate to use a soil test to verify conditions and to use dolomitic limestone or magnesium fertilization or to add magnesium to the feed.

Nitrogen

Harvested crops remove more nitrogen than any other nutrient from Illinois soils. Erosion reduces the nitrogen content of soils because the surface soil is richest in nitrogen and erodes first. Further nitrogen losses occur as a result of denitrification and leaching. About 40 percent of the original nitrogen and organic-matter content has been lost from typical Illinois soils since farming began.

The use of nitrogen fertilizer is necessary if Illinois agriculture is to be competitive in the world market. Low grain prices, along with concern for the environment, make it imperative that all nitrogen fertilizers be used in the most efficient manner possible. Factors that influence efficiency of fertilizer use are discussed in the following sections.

Rate of application

Corn. Yield goal is one of the major considerations to use in determining the optimum rate of nitrogen application for corn. These goals should be established for each field, taking into account the soil type and management level under which the crop will grow.

For Illinois soils, suggested productivity-index values are given in Illinois Cooperative Extension Service Circular 1156, *Soil Productivity in Illinois.* Yield goals are presented for both basic and high levels of management. For fields that will be under exceptionally high management, a 15- to 20-percent increase in the values given for high levels of management would be reasonable. Annual variations in yield of 20 percent above or below the productivity-index values are common because of variations in weather conditions. However, applying nitrogen fertilizer for yields possible in the most favorable year will not result in maximum net return when averaged over all years.

The University of Illinois Department of Agronomy has conducted research trials designed to determine the optimum nitrogen rate for corn under varying soil and climatic conditions.

The results of these experiments show that average economic optimum nitrogen rates varied from 1.22 to 1.32 pounds of nitrogen per bushel of corn produced when nitrogen was applied in the spring (Table 42). The lower rate of application (1.22 pounds) would be recommended at a corn-nitrogen price ratio (corn price per bushel to nitrogen price per pound) of between 10:1 and 20:1, and the higher rate (1.32 pounds) at a price ratio of 20:1 or greater.

As would be expected, the nitrogen requirement was lower at sites having a corn-soybean rotation than at sites with continuous corn. (See the subsection about rate adjustments page 47.)

With the exception of Dixon, which was based on limited data, Brownstown and DeKalb had the highest nitrogen requirement per bushel of corn produced. In part, this higher requirement may be the result of the higher denitrification losses that frequently have been observed at Brownstown and DeKalb.

Based on these results, Table 43 gives examples of the recommended rate of nitrogen application for selected Illinois soils under a high level of management.

Soybeans. Based on average Illinois corn and soybean yields from 1984-85 and average nitrogen content of the grain for these two crops, the total nitrogen removed per acre by soybeans was greater than that removed by corn (soybeans, 148 pounds of nitrogen per acre; corn, 96 pounds of nitrogen per acre). Recent research results from the University of Illinois, however, indicate that when properly nodulated soybeans were grown at the proper soil pH, symbiotic fixation was equivalent to 63 percent of the nitrogen removed in harvested grain. Thus, net nitrogen removal by soybeans was less than that of corn (corn, 96; soybeans, 55).

This net removal of nitrogen by soybeans in 1984-85 was equivalent to 24 percent of the amount of fertilizer nitrogen used in Illinois. On the other hand, symbiotic fixation of nitrogen by soybeans in Illinois (420,000 tons of N) was equivalent to 55 percent of the fertilizer nitrogen used in Illinois.

Even though there is a rather large net nitrogen removal from soil by soybeans (55 pounds of nitrogen per acre), research at the University of Illinois has generally indicated no soybean yield increase caused by either residual nitrogen remaining in the soil or nitrogen fertilizer applied for the soybean crop.

1. *Residual from nitrogen applied to corn (Table 44).* Soybean yields at four locations were not increased by residual nitrogen remaining in the soil, even when nitrogen rates as high as 320 pounds per acre had been applied to corn the previous year.
2. *Nitrogen on continuous soybeans (Table 45).* After 18 years of continuous soybeans at Hartsburg, yields were unaffected by nitrogen fertilizer application.
3. *High rates of added nitrogen (Table 46).* In 1968 a study was started at Urbana using moderate rates of nitrogen. Rates were increased in 1969 so that the higher rates would furnish more than the total nitrogen needs of soybeans. Yields were not affected by nitrogen in 1968; but with 400 pounds per acre of nitrogen, a tendency toward a yield increase occurred in 1969 and 1970. However, the yield increase would not pay for the added nitrogen at current prices.

Wheat, oats, and barley. The rate of nitrogen to apply on wheat, oats, and barley is dependent on soil type, crop and variety to be grown, and future cropping intentions (Table 47). Light-colored soils (low in organic matter) require the highest rate of nitrogen application because they have a low capacity to supply nitrogen. Deep, dark-colored soils require lower rates of nitrogen application for maximum yields. Estimates of organic-matter content for soils of Illinois may be obtained from Agronomy Fact Sheet SP-36, *Average Organic Matter Content in Illinois Soil Types,* or by using Uni-

Table 42. Economic Optimum Nitrogen Rate Experimentally Determined for Eight Locations as Affected by Corn-Nitrogen Price Ratios

Location and rotation	Corn-nitrogen price ratio			
	10:1		20:1	
	Optimum yield, bu/acre	Optimum N rate, lb/bu	Optimum yield, bu/acre	Optimum N rate, lb/bu
Brownstown (continuous corn)	83	1.30	86	1.47
Carthage (continuous corn)	144	1.22	147	1.29
DeKalb (continuous corn)	141	1.28	143	1.31
Urbana (continuous corn)	171	1.17	173	1.24
Average of continuous corn		1.24		1.33
Dixon (corn-soybeans)	131	1.37	134	1.58
Hartsburg (corn-soybeans)	156	1.19	157	1.27
Oblong (corn-soybeans)	123	1.11	126	1.23
Toledo (corn-soybeans)	123	1.12	124	1.20
Average of corn-soybeans		1.20		1.32
Average of all locations		1.22		1.32

Table 43. Nitrogen Recommendations for Selected Illinois Soils Under High Level of Management

Soil type	Corn-nitrogen price ratio	
	10:1	20:1
	nitrogen recommendation, lb/acre	
Muscatine silt loam	205	220
Ipava silt loam	200	215
Sable silty clay loam	190	205
Drummer silty clay loam	185	200
Plano silt loam	185	200
Hartsburg silty clay loam	175	190
Fayette silt loam	155	170
Clinton silt loam	155	170
Cowden silt loam	145	160
Cisne silt loam	140	150
Bluford silt loam	125	135
Grantsburg silt loam	115	125
Huey silt loam	80	85

Table 44. Soybean Yields at Four Locations as Affected by N Applied to Corn the Preceding Year (Four-Year Average)

N applied to corn, lb/acre	Soybean yield				
	Aledo	Dixon	Elwood	Kewanee	Average
	bushels per acre				
0	48	40	37	40	41
80	49	40	36	38	41
160	48	39	36	40	41
240	48	42	36	40	41
320	48	42	36	37	41

versity of Illinois publication AG-1941, *Color Chart for Estimating Organic Matter in Mineral Soils.*

Nearly all modern varieties of wheat have been selected for improved standability; thus concern about nitrogen-induced lodging has decreased considerably. Varieties of oats, although substantially improved with regard to standability, will still lodge occasionally; and nitrogen should be used carefully. Barley varieties, especially varieties of spring barley, are prone to lodging; thus rates of nitrogen application shown in Table 47 should not be exceeded.

Table 45. Yield of Continuous Soybeans with Rates of Added N at Hartsburg

Nitrogen, lb/acre/year	Soybean yield	
	1968-71	1954-71
	bushels per acre	
0	43	37
40	42	36
120	43	37

Table 46. Soybean Yields as Affected by High Rates of Nitrogen

Nitrogen, lb/acre			Soybean yield, bu/acre		
1968	1969	1970	1968	1969	1970
0	0	0	54	53	40
40	200	200	54	57	41
80	400	400	56	57	45
120	800	800	53	55	42
160	1,600	1,600	55	34	36

Some wheat and oats in Illinois serve as a companion crop for legume or legume-grass seedings. On those fields, it is best to apply nitrogen fertilizer at well below the optimum rate because unusually heavy vegetative growth of wheat or oats competes unfavorably with the young forage seedlings (Table 47). Seeding rates for small grains should also be somewhat lower if used as companion seedings.

The introduction of nitrification inhibitors and improved application equipment now provide two options for applying nitrogen to wheat. Research has shown that when the entire amount of nitrogen needed is applied in the fall with a nitrification inhibitor the resulting yields are equivalent to that obtained when a small portion of the total need was fall applied and the remainder was applied in early spring. Producers who are frequently delayed in applying nitrogen in the spring because of muddy fields may wish to

Table 47. Recommended Nitrogen Application Rates for Wheat, Oats, and Barley

Soil situation	Organic-matter content	Fields with alfalfa or clover seeding: Wheat	Fields with alfalfa or clover seeding: Oats and barley	Fields with no alfalfa or clover seeding: Wheat	Fields with no alfalfa or clover seeding: Oats and barley
		nitrogen, pounds per acre			
Soils low in capacity to supply nitrogen: inherently low in organic matter (forested soils)	<2%	70-90	60-80	90-110	70-90
Soils medium in capacity to supply nitrogen: moderately dark-colored soils	2-3%	50-70	40-60	70-90	50-70
Soils high in capacity to supply nitrogen: all deep, dark-colored soils	>3%	30-50	20-40	50-70	30-50

consider fall application with a nitrification inhibitor. For fields that are not usually wet in the spring, either system of application will provide equivalent yields.

The amount of nitrogen needed for good fall growth is not large because the total uptake in roots and tops before cold weather is not likely to exceed 30 to 40 pounds per acre.

Hay and pasture grasses. The species grown, period of use, and yield goal determine optimum nitrogen fertilization (Table 48). The lower rate of application is recommended on fields where inadequate stands or moisture limits production.

Kentucky bluegrass is shallow rooted and susceptible to drought. Consequently, the most efficient use of nitrogen by bluegrass is from an early-spring application, with September application a second choice. September fertilization stimulates both fall and early-spring growth.

Orchardgrass, smooth bromegrass, tall fescue, and reed canarygrass are more drought tolerant than bluegrass and can use higher rates of nitrogen more effectively. Because more uniform pasture production is obtained by splitting high rates of nitrogen, two or more applications are suggested.

If extra spring growth can be utilized, make the first nitrogen application in March in southern Illinois, early April in central Illinois, and mid-April in northern Illinois. If spring growth is adequate without extra nitrogen, the first application may be delayed until after the first harvest or grazing cycle to distribute production more uniformly throughout the summer. Total production likely will be less, however, if nitrogen is applied after first harvest rather than in early spring. Usually the second application of nitrogen is made after the first harvest or first grazing cycle; to stimulate fall growth, however, this application may be deferred until August or early September.

Legume-grass mixtures should not receive nitrogen if legumes make up at least 30 percent of the mixture. Because the main objective is to maintain the legume, the emphasis should be on applying phosphorus and potassium rather than nitrogen.

After the legume has declined to less than 30 percent of the mixture, the objective of fertilizing is to increase the yield of grass. The suggested rate of nitrogen is about 50 pounds per acre when legumes make up 20 to 30 percent of the mixture.

Rate adjustments

In addition to determining nitrogen rates, consideration should be given to other agronomic factors that influence available nitrogen. These factors include past cropping history and the use of manure (Table 49), as well as the date of planting.

Experiments conducted at the Carthage experimental field comparing nitrogen requirements of continuous corn and corn following soybeans indicate a soil nitrogen contribution of 30 to 40 pounds per acre at the lower rates of applied nitrogen and 20 to 30 pounds per acre at the higher rates of nitrogen application (Figure 9). At Elwood, the yield differential between continuous corn and corn-soybeans continues to widen at higher rates of nitrogen application. It is

Table 48. Nitrogen Fertilization of Hay and Pasture Grasses

Species	Time of application: Early spring	After first harvest	After second harvest	Early September
	nitrogen, pounds per acre			
Kentucky bluegrass	60-80			(see text)
Orchardgrass	75-125	75-125		
Smooth bromegrass	75-125	75-125		50[a]
Reed canarygrass	75-125	75-125		50[a]
Tall fescue for winter use		100-125	100-125	50[a]

[a] Optional if extra fall growth is needed.

Table 49. Adjustments in Nitrogen Recommendations

Crop to be grown	After soybeans	1st year after alfalfa or clover, Plants/sq ft: 5	2-4	<2	2nd year after alfalfa or clover, Plants/sq ft: 5	<5	Manure
	nitrogen, reduction, lb/acre						
Corn	40	100	50	0	30	0	5[a]
Wheat	10	30	10	0	0	0	5[a]

Factors resulting in reduced nitrogen requirement (columns After soybeans through Manure).

[a] Nitrogen contribution in pounds per ton of manure.

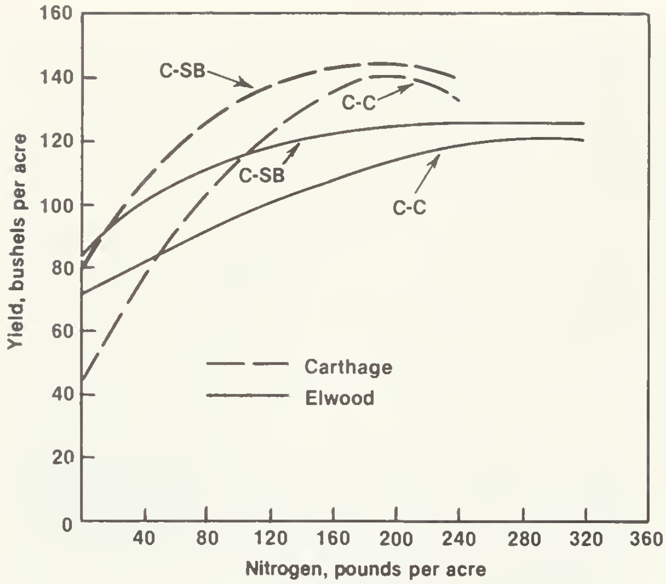


Figure 9. Effect of crop rotation and applied nitrogen on corn yield.

doubtful that this yield differential is entirely the result of nitrogen contributions from the soybeans. The contribution of legumes, either soybeans or alfalfa, to wheat will be less than the contribution to corn because the oxidation of the organic nitrogen from these legumes will not be as rapid in early spring, when the nitrogen needs of small grain are greatest, as it is in the summer, when nitrogen needs of corn are greatest.

Depending on the crop grown, the nitrogen credit from idled acres may be positive or negative. Plowing under a good stand of a legume that had good growth will result in a nitrogen contribution of 60 to 80 pounds of nitrogen per acre. If either stand or growth of the legume was poor or if corn was zero-tilled into a good legume stand that had good growth, the nitrogen rates could be reduced to 40 to 60 pounds per acre. Because most of the net nitrogen gained from first-year legumes will be in the herbage, fall grazing will reduce the nitrogen contribution to 30 to 50 pounds per acre. If sorghum residues are incorporated into the soil, an additional 30 to 40 pounds of nitrogen should be applied per acre.

Nutrient content of manure will vary, depending on source and method of handling (Table 50). Additionally, the availability of the total nitrogen content will vary, depending on method of application. When incorporated during or immediately after application, about 50 percent of the total nitrogen in dry manure and 50 to 60 percent of the total nitrogen in liquid manure will be available for the crop that is grown during the year following manure application.

Research at the Northern Illinois Research Center for several years showed that as planting was delayed, less nitrogen fertilizer was required for most profitable yield. Based upon that research, Illinois agronomists suggest that for each week of delay in planting after the optimum date for the area, the nitrogen rate can be reduced 20 pounds per acre down to 80 to 90 pounds per acre as the minimum for very late planting in a corn-soybean cropping system. Suggested reference dates are April 10 to 15 in southern Illinois, April 20 to May 1 in central Illinois, and May 1 to 10 in northern Illinois. This adjustment is, of course, possible only if the nitrogen is sidedressed.

Because of the importance of the planting date, farmers are encouraged not to delay planting just to apply nitrogen fertilizer: Plant, then sidedress.

Table 50. Average Composition of Manure

Kind of animal	Nutrients (lb/ton)		
	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
Dairy cattle	11	5	11
Beef cattle	14	9	11
Hogs	10	7	8
Chicken	20	16	8
Dairy cattle (liquid)	5(26)[a]	2(11)	4(23)
Beef cattle (liquid)	4(21)	1(7)	3(18)
Hogs (liquid)	10(56)	5(30)	4(22)
Chicken (liquid)	13(74)	12(68)	5(27)

[a] Parenthetical numbers are pounds of nutrients per 1,000 gallons.

Reactions in the soil

Efficient use of nitrogen fertilizer requires an understanding of how nitrogen behaves in the soil. Key points to consider are the change from ammonium (NH_4^+) to nitrate (NO_3^-) and the movements and transformations of nitrate.

A high percentage of the nitrogen applied in Illinois is in the ammonium form or converts to ammonium (anhydrous ammonia and urea, for example) soon after application. Ammonium nitrogen is held by the soil clay and organic matter and cannot move very far until it nitrifies (changes from ammonium to nitrate). In the nitrate form, nitrogen can be lost by either denitrification or leaching (Figure 10).

Denitrification. Denitrification is believed to be the main process by which nitrate and nitrite nitrogen are lost, except on sandy soils, where leaching is the major pathway. Denitrification involves only nitrogen that is in the form of either nitrate (NO_3^-) or nitrite (NO_2^-).

The amount of denitrification depends mainly on (1) how long the surface soil is saturated; (2) the temperature of the soil and water; (3) the pH of the soil; and (4) the amount of energy material available to denitrifying organisms.

When water stands on the soil or when the surface is completely saturated in late fall or early spring, nitrogen loss is likely to be small because (a) much nitrogen is still in the ammonium rather than nitrate form; and (b) the soil is cool, and denitrifying organisms are not very active.

Many fields in east central Illinois and, to a lesser extent, in other areas have low spots where surface water collects at some time during the spring or early summer. The flat claypan soils also are likely to be

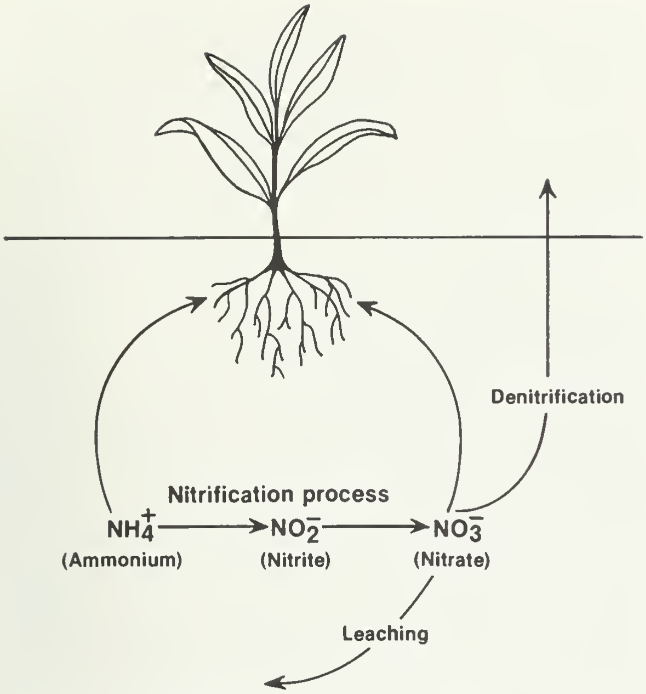


Figure 10. Nitrogen reactions in the soil.

saturated, though not flooded, during that time. Sidedressing would avoid the risk of spring loss on these soils but would not affect midseason loss. Unfortunately, these are the soils on which sidedressing is difficult in wet years.

New scientific procedures now make it possible to directly measure denitrification losses. Results collected over the past few years indicated that when soils were saturated for 3 to 4 days, losses of 30 to 40 pounds of nitrogen per acre occurred even though water was ponded for only a few hours. These losses resulted in a yield loss of 10 to 20 bushels per acre. Increasing the time that soils were saturated to 6 days resulted in losses of 60 to 70 pounds of nitrogen per acre. As more results are collected, agronomists will be able to predict more accurately the nitrogen loss under specific conditions and, more importantly, to predict the response to added nitrogen.

Leaching. In silt loams and clay loams, one inch of rainfall moves down about 5 to 6 inches, though some of the water moves farther in large pores through the profile and carries nitrates with it.

In sandy soils, each inch of rainfall moves nitrates down about one foot. If the total rainfall at one time is more than 6 inches, little nitrate will be left within the rooting depth on sands.

Between rains, some upward movement of nitrates occurs in moisture that moves toward the surface as the surface soil dries. The result is that it is difficult to predict how deep the nitrate has moved based only on cumulative rainfall.

When trying to estimate the depth of leaching of nitrates in periods of very intensive rainfall, two points need to be considered. First, the rate at which water can enter the surface of silt and clay loams may be less than the rate of rainfall, which means that much of the water runs off the surface either into low spots or into creeks and ditches. Second, the soil may be saturated already. In either of these cases, the nitrates will not move down the 5 to 6 inches per inch of rain as suggested above.

Corn roots usually penetrate to 6 feet in Illinois soils. Thus, nitrates that leach only to 3 to 4 feet are well within normal rooting depth unless they reach tile lines and are drained from the field.

Nitrification inhibitors

As Figure 10 shows, nitrification converts ammonium nitrogen into the nitrate form of nitrogen and thereby increases the potential for loss of soil nitrogen. Use of nitrification inhibitors can retard this conversion. When inhibitors were properly applied in one experiment, as much as 42 percent of soil-applied ammonia remained in the ammonium form through the early part of the growing season, in contrast with only 4 percent that remained when inhibitors were not used. Inhibitors can therefore have a significant effect on crop yields. The benefit from using an inhibitor will vary, however, with the soil condition, time of year, type of soil, geographic location, rate of nitrogen application, and weather conditions that occur after the nitrogen is applied and before it is absorbed by the crop.

Considerable research throughout the Midwest has shown that only under wet soil conditions will inhibitors significantly increase yields. When inhibitors were applied in years of excessive rainfall, increases in corn yield ranged from 10 to 30 bushels per acre; when moisture conditions were not as conducive to denitrification or leaching, inhibitors produced no increase.

For the first 4 years of one experiment conducted by the University of Illinois, nitrification inhibitors produced no effect on grain yields because soil moisture levels were not sufficiently high. In early May of the fifth year, however, when soils were saturated with water for a long time, the application of an inhibitor in the preceding fall significantly increased corn yields (Figure 11). Furthermore, at a nitrogen application rate of 150 pounds per acre, the addition of an inhibitor increased grain yields more than did the addition of another 40 pounds of nitrogen (Figure 11). Under the conditions of that experiment, therefore, it was more economical to use an inhibitor than to apply more nitrogen.

Because soils normally do not remain saturated with water for very long during the growing season after a sidedressing operation, the probability of benefiting from the use of a nitrification inhibitor with sidedressed nitrogen is less than from their use with either fall- or spring-applied nitrogen. Moreover, the short time between application and absorption by the crop greatly reduces the potential for nitrogen loss.

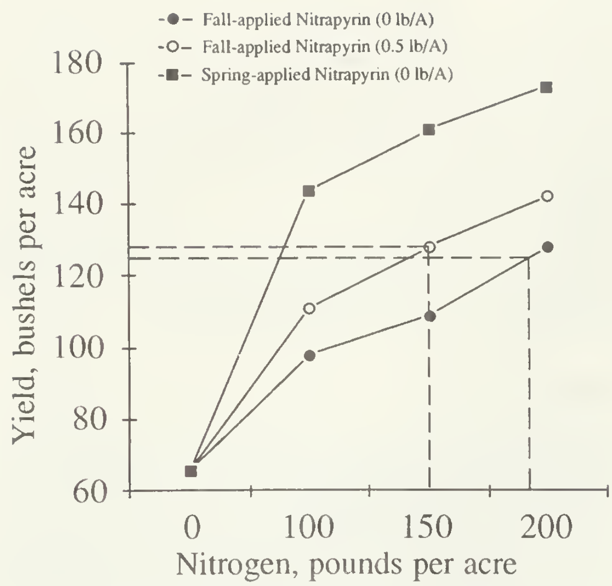


Figure 11. Effect of nitrification inhibitors on corn yields at varying nitrogen application rates, DeKalb, 1979.

The longer the period between nitrogen application and absorption by the crop, the greater the probability that nitrification inhibitors will contribute to higher yields. The length of time, however, that fall-applied inhibitors will remain in the soil is partly dependent on soil temperature. On one plot, a Drummer soil that had received an inhibitor application when soil temperatures were 55°F, retained nearly 50 percent of the applied ammonia in ammonium form for about 5 months. When soil temperatures were 70°F, it retained the same amount of ammonia for only 2 months. Fall application of nitrogen with inhibitors should therefore be delayed until soil temperatures are no higher than 60°F; and though temperatures may decrease to 60°F in early September, it is advisable to delay applications until the last week in September in northern Illinois and the first week in October in central Illinois.

In general, poorly or imperfectly drained soils will probably benefit the most from nitrification inhibitors. Moderately well-drained soils that undergo frequent periods of 3 or more days of flooding in the spring will also benefit. Coarse-textured soils (sands) are likely to benefit more than soils with finer textures because the coarse-textured soils have a higher potential for leaching.

Time of application and geographic location must be considered along with soil type when determining whether to use a nitrification inhibitor. Employing nitrification inhibitors can significantly improve the efficiency of fall-applied nitrogen on the loams, silts, and clays of central and northern Illinois in years when the soil is very wet in the spring. At the same time, presently available inhibitors will not adequately reduce the rate of nitrification in the low organic-matter soils of southern Illinois when nitrogen is applied in the fall for the following year's corn because the soil's lower organic-matter content and the warmer temperatures of southern Illinois, both in late fall and early spring, will cause the inhibitor to degrade too rapidly. Futhermore, applying an inhibitor on sandy soils in the fall will not adequately reduce nitrogen loss because the potential for leaching is too high. Therefore, fall applications of nitrogen with inhibitors are not recommended for sandy soils or for soil with low organic-matter content, especially for those soils found south of Interstate Highway 70.

In the spring, preplant applications of inhibitors may be beneficial on nearly all types of soil from which nitrogen loss frequently occurs, especially on sandy and poorly drained soils. Again, inhibitors are more likely to have an effect when subsoils are recharged with water than when subsoils are dry at the beginning of spring.

Nitrification inhibitors are most likely to increase yields when nitrogen is applied at or below the optimum rate. When nitrogen is applied at a rate greater than that required for optimum yields, benefits from an inhibitor are unlikely, even when moisture in the soil is excessive.

Inhibitors should be viewed as soil management tools that can be used to reduce nitrogen loss. It is not safe to assume, however, that the use of a nitrification inhibitor will make it possible to reduce nitrogen rates below those currently recommended, because those rates were developed with the assumption that no significant amount of nitrogen would be lost.

Time of nitrogen application

In recent years, farmers in central and northern Illinois have been encouraged to apply nitrogen in nonnitrate form in the late fall any time after the soil temperature at 4 inches was below 50°F, except on sandy, organic, or very poorly drained soils.

The 50°F level for fall application is believed to be a realistic guideline for farmers. Applying nitrogen earlier involves risking too much loss (Figure 12). Later application involves risking wet or frozen fields, which

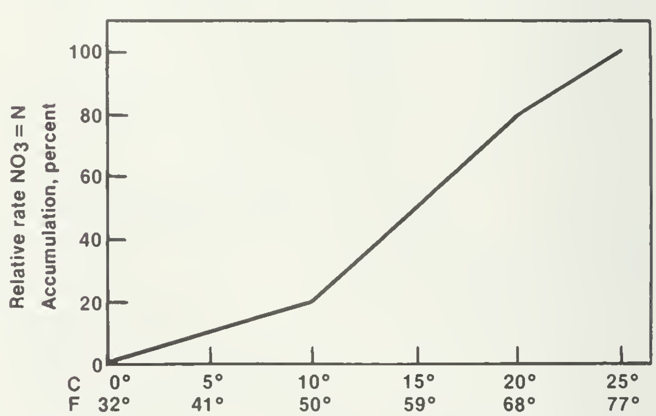


Figure 12. Influence of soil temperature on the relative rate of NO_3 accumulation in soils.

would prevent application and fall tillage. Average dates on which these temperatures are reached are not satisfactory guides because of the great variability from year to year. Soil thermometers should be used to guide fall applications of nitrogen.

In Illinois, most of the nitrogen applied in late fall or very early spring will be converted to nitrate by corn-planting time. Though the rate of nitrification is slow (Figure 12), the soil temperature is between 32°F and 40° to 45°F for a long period.

The results from 18 experiments in central and northern Illinois (Figure 13) show that fall-applied ammonium nitrate (half ammonium, half nitrate) was less effective than spring-applied nitrogen. There are two ways to compare efficiency. For example, in Figure 13, left, 120 pounds of nitrogen applied in the fall produced 92 percent as much increase as the same amount applied in the spring. But looked at another way, it requires 120 pounds of fall-applied nitrogen to produce as much yield increase as was produced by 100 pounds applied in the spring (Figure 13, right). At higher nitrogen rates, the comparisons become less favorable for fall application because the yield leveled off 6 to 8 bushels below that from spring application.

In consideration of the date at which nitrates are formed and the conditions that prevail thereafter, the difference in susceptibility to denitrification and leaching loss between late-fall and early-spring applications of ammonium sources is probably small. Both are, however, more susceptible to loss than is nitrogen applied at planting time or as a sidedressing.

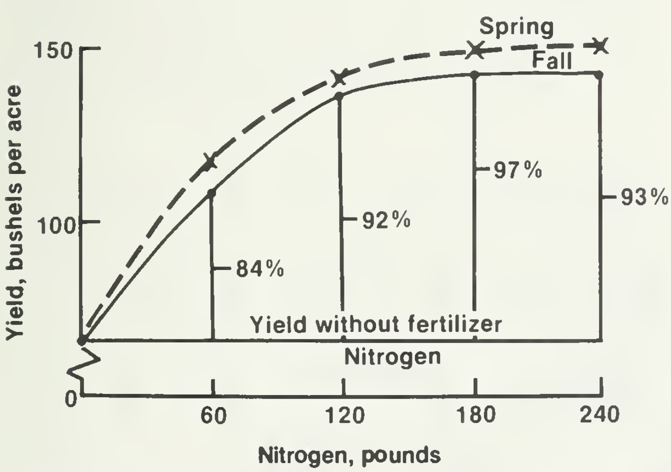
Anhydrous ammonia nitrifies more slowly than other forms and is slightly preferred for fall applications. It is well suited to early-spring application, provided the soil is dry enough for good dispersion of ammonia and closure of the applicator slit.

Sidedress application. Results collected from studies in Illinois indicated that nitrogen injected in every other space between rows was comparable in yield to injection in all inter-row spaces. This finding was true irrespective of tillage system (Table 51) or nitrogen rate (Table 52). Furthermore, this outcome should be expected, as even with every-other row injection, each row will have nitrogen applied on one side or the other (Figure 14). While all of the results to date were obtained with anhydrous ammonia, there is no reason to believe that the same results would not be obtained with injected nitrogen solutions.

Use of wider injection spacing at sidedressing allows for a reduction in power requirement for a given applicator width or use of a wider applicator with the same power requirement. From a practical standpoint, the lower power requirement will frequently mean a smaller tractor and associated smaller tire, making it easier to maneuver between the rows and also giving less compaction next to the row. With this system, injector positions can be adjusted to avoid placing an injector in the wheel track. When matching the driving pattern for planters of 8, 12, 16, or 24 rows, the outside two injectors must be adjusted to half-rate application, as the injector will go between those two rows twice if one avoids the wheel track.

Winter application. Based on observations in 1986, the risk of nitrogen loss through volatilization associated with winter application of urea for corn on frozen soils is too great to consider the practice unless one is assured of at least one-half inch of precipitation occurring within 4 to 5 days after application. In most years, application of urea on frozen soils has been an effective practice for wheat.

Aerial application. Recent research at the University of Illinois has indicated that an aerial application of dry urea will result in increased yield. This practice should not be considered a replacement for normal nitrogen application but rather an emergency treatment



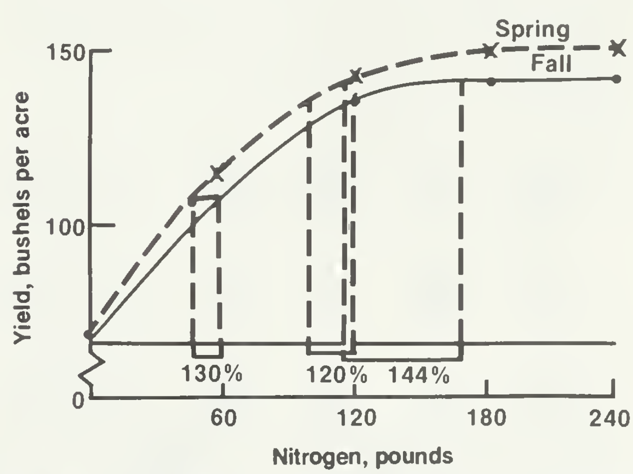


Figure 13. Comparison of fall- and spring-applied ammonium nitrate, 18 experiments in central and northern Illinois, 1966-1969 (DeKalb, Carthage, Carlinville, and Hartsburg). Figure at left shows increased yield from fall fertilizer application as a percent of yield increases achieved when fertilizer was applied in the spring. Figure at right shows amount of fertilizer you need to apply in the fall to obtain a given yield as a percent of the fertilizer needed to obtain that same yield with spring application.

Table 51. Effect on Corn Yield of Ammonia Knife Spacing with Different Tillage Systems at Two Locations in Illinois

Injector spacing, in.	Yield, bushels per acre			
	Plow	Chisel	Disk	No-Till
	DeKalb			
30	159	157	163	146
60	158	157	157	143
	Elwood			
30	...	119	121	118
60	...	117	125	121

Table 52. Effect on Corn Yield of Injector Spacing of Ammonia Applied at Varying Rates of Nitrogen

Injector spacing, in.	Yield, bushels per acre		
	N, 120 lb/acre	N, 180 lb/acre	N, 240 lb/acre
	DeKalb, 1985		
30	177	178	183
60	173	174	186
	DeKalb, 1986		
30	166	175	180
60	167	168	178

in situations where corn is too tall for normal applicator equipment. Aerial application of nitrogen solutions on growing corn is not recommended, as extensive leaf damage will likely result if the rate of application is greater than 10 pounds of nitrogen per acre.

Which nitrogen fertilizer?

Most of the nitrogen fertilizer materials available for use in Illinois provide nitrogen in the combined form of ammonia, ammonium, urea, and nitrate. For many uses on a wide variety of soils, all forms are likely to produce about the same yield — provided that they are properly applied.

Ammonia. Nitrogen materials that contain free ammonia (NH_3), such as anhydrous ammonia or low-pressure solutions, must be injected into the soil to avoid loss of ammonia in gaseous form. Upon injection into the soil, ammonia quickly reacts with water to form ammonium (NH_4^+). In this positively charged form, the ion is not susceptible to gaseous loss because it is temporarily attached to the negative charges on clay and organic matter. Some of the ammonia reacts with organic matter to become a part of the soil humus.

On silt loam or soils with finer textures, ammonia will move about 4 inches from the point of injection. On more coarsely textured soils such as sands, ammonia may move 5 to 6 inches from the point of injection. If the depth of application is shallower than the distance of movement, some ammonia may move slowly to the soil surface and escape as a gas over a period of several days. On coarse-textured (sandy) soils, anhydrous ammonia should be placed 8 to 10 inches deep, whereas on silt-loam soils, the depth of application should be 6 to 8 inches. Anhydrous ammonia is lost more easily from shallow placement than is ammonia in low-pressure solutions. Nevertheless, low-pressure solutions contain free ammonia and thus need to be incorporated into the soil at a depth of 2 to 4 inches. Ammonia should not be applied to soils having a physical condition that would prevent closure of the applicator knife track. Ammonia will escape to the atmosphere whenever there is a direct opening from the point of injection to the soil surface.

You can damage seedlings if you do not take proper precautions when applying nitrogen materials that contain or form free ammonia. Damage may occur if you inject nitrogen material into soils that are so wet that the knife track does not close properly. If the soil dries rapidly, this track may open. You can also cause damage by applying nitrogen material to excessively dry soils, which allow the ammonia to move large distances before being absorbed. Finally, you can damage seedlings by using a shallower application than that suggested in the preceding paragraph. Generally, if you delay planting 3 to 5 days after you apply

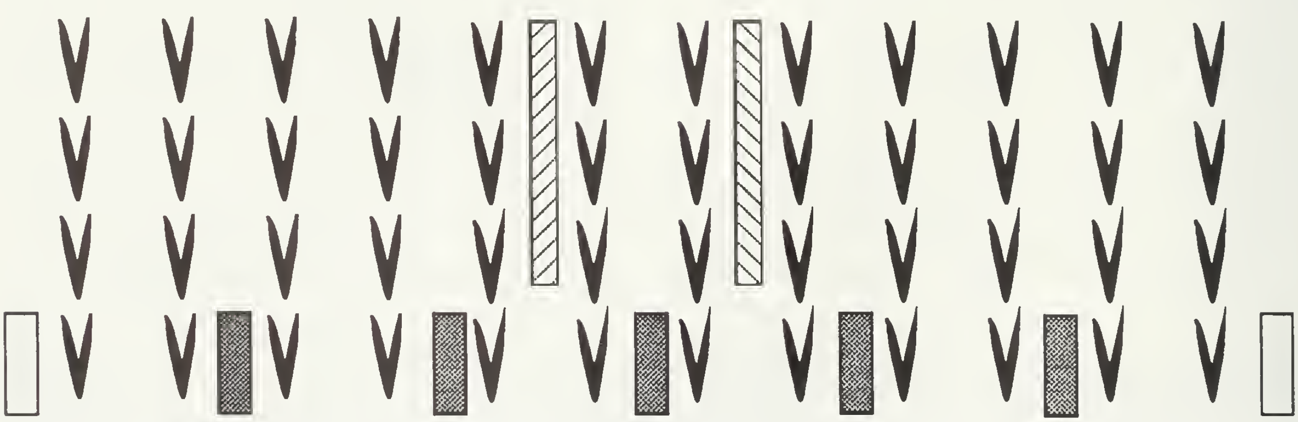


Figure 14. Schematic of every-other-row, sidedress nitrogen injection. Note that the outside two injectors are set at one-half rate because the injector will run between those two rows twice.

fertilizer, you will see little if any seedling damage. Under extreme conditions, however, seedling damage has been observed even when planting was delayed for 2 weeks after the fertilizer was applied.

Ammonium nitrate. Half of the nitrogen contained in ammonium nitrate is in the ammonium form and half is in the nitrate form. The part present as ammonium attaches to the negative charges on the clay and organic-matter particles and remains in that state until it is utilized by the plant or converted to the nitrate ions by microorganisms present in the soil. Because 50 percent of the nitrogen is present in the nitrate form, this product is more susceptible to loss from leaching and denitrification. Thus, ammonium nitrate should not be applied to sandy soils because of the likelihood of leaching, nor should it be applied far in advance of the time when the crop needs the nitrogen because of possible loss by denitrification.

Urea. The chemical formula for urea is $CO(NH_2)_2$. In this form, it is very soluble and moves freely up and down with soil moisture. After being applied to the soil, urea is converted to ammonia, either chemically or by the enzyme urease. The speed with which this conversion occurs depends largely on temperature. At low temperatures, conversion is slow; but at temperatures of 55°F or higher, conversion is rapid.

If the conversion of urea occurs on the soil surface or on the surface of crop residue or leaves, some of the resulting ammonia will be lost as a gas to the atmosphere. The potential for loss is greatest when:

1. Temperatures are greater than 55°F. Loss is less likely with winter or early-spring applications, but results show that the loss may be substantial if the materials remain on the surface of the soil for several days.
2. Considerable crop residue remains on the soil surface.
3. Application rates are greater than 100 pounds of nitrogen per acre.
4. The soil surface is moist and rapidly drying.
5. Soils have a low cation-exchange capacity.
6. Soils are neutral or alkaline in reaction.

Research conducted at both the Brownstown and Dixon Springs research centers has shown that surface application of urea for zero-till corn did not yield as well as ammonium nitrate (Table 53) in most years. In years when a rain was received within 1 or 2 days after application, urea resulted in as good a yield increase as did ammonium nitrate (that is, compared to results from early-spring application of ammonium nitrate at Dixon Springs in 1975). In other studies, urea that was incorporated soon after application yielded as well as ammonium nitrate.

Nitrogen solutions. The nonpressure nitrogen solutions that contain 28- to 32-percent nitrogen consist of a mixture of urea and ammonium nitrate. Typically, half of the nitrogen is from urea, and the other half is from ammonium nitrate. The constituents of these compounds will undergo the same reactions as described above for the constituents applied alone.

Experiments at DeKalb have shown a yield difference between incorporated and unincorporated nitrogen solutions that were spring-applied (Table 54). This difference associated with method of application is probably caused by volatilization loss of some nitrogen from the surface-applied solution containing urea.

Table 53. Effect of Source of Nitrogen for Zero-Till Corn

Nitrogen: Source	Nitrogen: Date of application	Nitrogen: Method of application	Nitrogen: Rate, lb/acre	Brownstown 1974-77 avg.	Dixon Springs 1974	Dixon Springs 1975
				yield, bu/acre		
Control	..	..	0	52	50	
Ammonium nitrate	early spring	surface	120	96	132	160
Urea	early spring	surface	120	80	106	166
Ammonium nitrate	early June	surface	120	106	151	187
Urea	early June	surface	120	99	125	132

Table 54. Effect of Source, Method of Application, and Rate of Spring-Applied Nitrogen on Corn Yield, DeKalb

Carrier and method of application	N (lb/acre)	Year 1976	Year 1977	Avg.
		yield, bu/acre		
None	0	66	61	64
Ammonia	80	103	138	120
28-percent N solution, incorporated	80	98	132	115
28-percent N solution, unincorporated	80	86	126	106
Ammonia	160	111	164	138
28-percent N solution, incorporated	160	107	157	132
28-percent N solution, unincorporated	160	96	155	126
Ammonia	240	112	164	138
28-percent N solution, incorporated	240	101	164	132
28-percent N solution, unincorporated	240	91	153	122
	FLSD.10	9.1	5.2	

Phosphorus and potassium

Inherent availability

Illinois has been divided into three regions in terms of inherent phosphorus-supplying power of the soil below the plow layer in dominant soil types (Figure 15).

High phosphorus-supplying power means that the soil test for available phosphorus (P_1 test) is relatively high and conditions are favorable for good root penetration and branching throughout the soil profile.

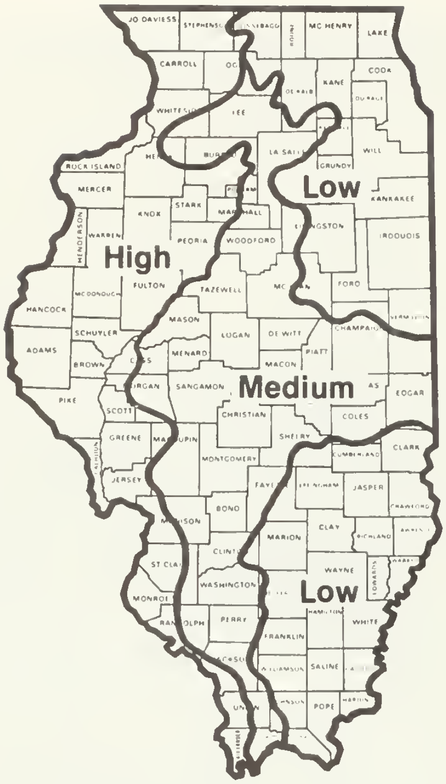


Figure 15. Phosphorus-supplying power.

Low phosphorus-supplying power may be caused by one or more of these factors:

1. A low supply of available phosphorus in the soil profile because (a) the parent material was low in P; (b) phosphorus was lost in the soil-forming process; or (c) the phosphorus is made unavailable by high pH (calcareous) material.
2. Poor internal drainage that restricts root growth.
3. A dense, compact layer that inhibits root penetration or branching.
4. Shallowness to bedrock, sand, or gravel.
5. Droughtiness, strong acidity, or other conditions that restrict crop growth and reduce rooting depth.

Regional differences in phosphorus-supplying power are shown in Figure 15. Parent material and degree of weathering were the primary factors considered in determining the various regions.

The "high" region is in western Illinois, where the primary parent material was more than 4 to 5 feet of loess that was high in phosphorus content. The soils are leached of carbonates to a depth of more than 3½ feet, and roots can spread easily in the moderately permeable profiles.

The "medium" region is in central Illinois, with arms extending into northern and southern Illinois. The primary parent material was more than 3 feet of loess over glacial till, glacial drift, or outwash. Some sandy areas with low phosphorus-supplying power occur in the region. In comparison with the high-phosphorus region, more of the soils are poorly drained and have less available phosphorus in the subsoil and substratum horizons. Carbonates are likely to occur at shallower depths than in the "high" region. The soils in the northern and central areas are generally free of root-restrictions, while soils in the southern arm are more likely to have root-restricting layers within the profile. Phosphorus-supplying power of soils of the region is likely to vary with natural drainage. Soils with good internal drainage are likely to have higher levels of available phosphorus in the subsoil and substratum. If internal drainage is fair or poor, phosphorus levels in the subsoil and substratum are likely to be low or medium.

In the "low" region in southeastern Illinois, the soils were formed from 2½ to 7 feet of loess over weathered Illinoisan till. The profiles are more highly weathered than in the other regions and are slowly or very slowly permeable. Root development is more restricted than in the "high" or "medium" regions. Subsoil levels of phosphorus may be rather high by soil test in some soils of the region, but this is partially offset by conditions that restrict rooting.

In the "low" region in northeastern Illinois, the soils were formed from thin loess (less than 3 feet) over glacial till. The glacial till, generally low in available phosphorus, ranges in texture from gravelly loam to clay in various soil associations of the region. In addition, shallow carbonates further reduce the phosphorus-supplying power of the soils of the region. Further, high bulk density and slow permeability in the subsoil and substratum restrict rooting in many soils of the region.

The three regions are delineated to show broad differences between them. Parent material, degree of weathering, native vegetation, and natural drainage vary within a region and cause variation in the soil's phosphorus-supplying power. It appears, for example, that soils developed under forest cover have more available subsoil phosphorus than those developed under grass.

Illinois is divided into two general regions for potassium, based on cation-exchange capacity (Figure 16). Important differences exist, however, among soils within these general regions because of differences in the following six factors.

1. The amount of clay and organic matter, which influences the exchange capacity of the soil.
2. The degree of weathering of the soil material, which affects the amount of potassium that has been leached out.
3. The kind of clay mineral.
4. Drainage and aeration, which influence uptake of potassium (K).
5. The parent material from which the soil formed.
6. Compactness or other conditions that influence root growth.

Soils that have a cation-exchange capacity less than 12 meq./100 gram are classified as having low cation-exchange capacity. These soils include the sandy soils

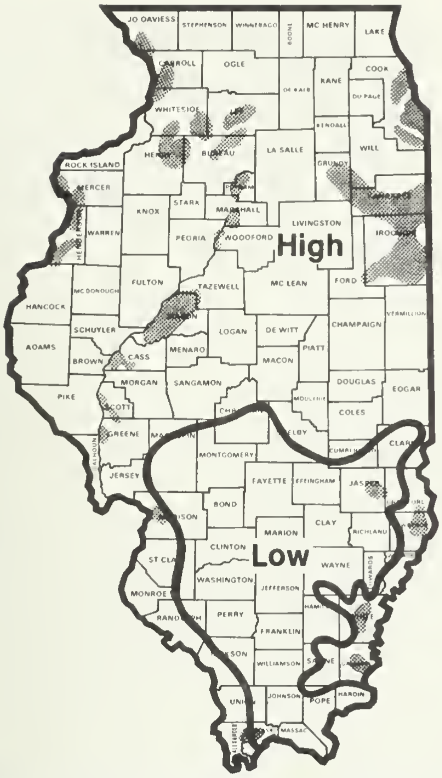


Figure 16. Cation-exchange capacity. The shaded areas are sands with low cation-exchange capacity.

because minerals from which these soils developed are inherently low in potassium. Sandy soils also have very low cation-exchange capacities and thus do not hold much reserve potassium.

Silt-loam soils in the "low" area in southern Illinois (claypans) are relatively older soils in terms of soil development; consequently, much more of the potassium has been leached out of the rooting zone. Furthermore, wetness and a platy structure between the surface and subsoil may interfere with rooting and with potassium uptake early in the growing period, even though roots are present.

Rate of fertilizer application

Minimum soil-test levels required to produce optimum crop yields vary depending on the crop to be grown and the soil type (Figures 17 and 18). Near maximum yields of corn and soybeans will be obtained when levels of available phosphorus are maintained at 30, 40, and 45 pounds per acre for soils in the high, medium, and low phosphorus-supplying regions, respectively. Potassium soil test levels at which optimum yields of these two crops will be attained are 260 and 300 pounds of exchangeable potassium per acre for soils in the low and high cation-exchange capacity regions, respectively. Because phosphorus, and on most soils also potassium, will not be lost from the soil system other than through crop removal or soil erosion and because these are minimum values required for

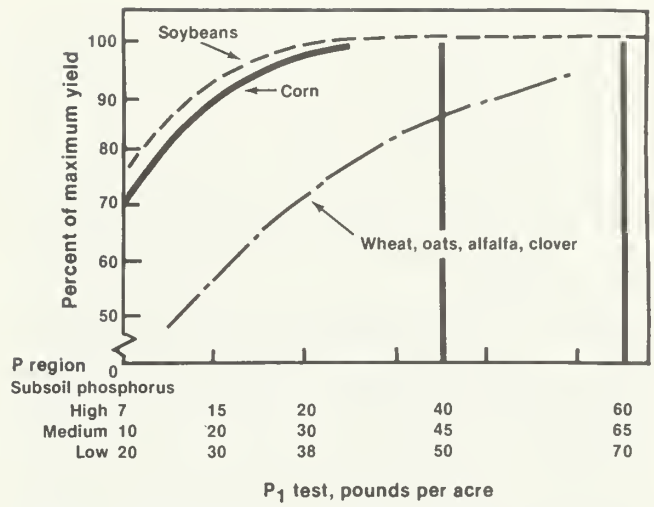


Figure 17. Relationship between expected yield and soil-test phosphorus.

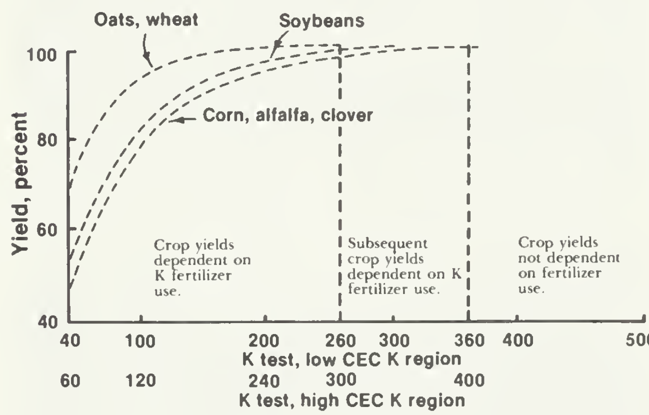


Figure 18. Relationship between expected wheat or oat yield and soil-test phosphorus and potassium.

optimum yields, it is recommended that soil-test levels be built up to 40, 45, and 50 pounds per acre of phosphorus for soils in the high, medium, and low phosphorus-supplying regions, respectively.

Depending on the inherent soil-test level, the amount of fertilizer recommended may consist of a buildup plus maintenance, maintenance, or no fertilizer suggestion. The buildup addition is the amount of material required to increase the soil test to the desired level. The maintenance addition is the amount required to replace the amount that will be removed by the crop to be grown.

Buildup plus maintenance. When soil-test levels are below the desired values, it is suggested that enough fertilizer be added to build the soil test to the desired goal plus enough to replace what the crop will remove. At these test levels, the yield of the crop to be grown will be affected by the amount of fertilizer applied that year.

Maintenance. When the soil-test levels are between

the minimum and 20 pounds above the minimum, for phosphorus (that is, 40 to 60, 45 to 65, or 50 to 70) or between the minimum and 100 pounds above the minimum for potassium (that is, 260 to 360 or 300 to 400), apply enough to replace what the crop to be grown is expected to remove. The yield of the current crop may not be affected by the fertilizer addition that year, but the yield of subsequent crops will be adversely affected if the materials are not applied to maintain soil-test levels.

No fertilizer. Although it is recommended that soil-test levels be maintained slightly above the level at which optimum yield would be expected, it would not be economical to attempt to maintain the values at excessively high levels. *Therefore, it is suggested that no phosphorus be applied if P_1 values are higher than 60, 65, or 70, respectively, for soils in the high, medium, and low phosphorus-supplying regions. No potassium is suggested if test levels are above 360 or 400 for the low and high cation-exchange capacity regions, unless crops that remove large amounts of potassium (such as alfalfa or corn silage) are being grown.* When soil-test levels are between 400 and 600 pounds per acre of potassium and corn silage or alfalfa is being grown, the soil should be tested every 2 years instead of 4 or maintenance levels of potassium should be added to ensure that soil-test levels do not fall below the point of optimum yields.

Table 55. Amount of Phosphorus (P_2O_5) Required To Build Up the Soil (based on buildup occurring over a four-year period; 9 pounds of P_2O_5 per acre required to change P_1 soil test 1 pound)

P_1 test, lb/acre	Pounds of P_2O_5 to apply per acre *each year* for soils with supplying power rated		
	Low	Medium	High
4	103	92	81
6	99	88	76
8	94	83	72
10	90	79	68
12	86	74	63
14	81	70	58
16	76	65	54
18	72	61	50
20	68	56	45
22	63	52	40
24	58	47	36
26	54	43	32
28	50	38	27
30	45	34	22
32	40	29	18
34	36	25	14
36	32	20	9
38	27	16	4
40	22	11	0
42	18	7	0
44	14	2	0
45	11	0	0
46	9	0	0
48	4	0	0
50	0	0	0

Phosphorus

Buildup. Research has shown that, as an average for Illinois soils, 9 pounds of P_2O_5 per acre are required to increase the P_1 soil test by 1 pound. Therefore, the recommended rate of buildup phosphorus is equal to nine times the difference between the soil-test goal and the actual soil-test value. The amount of phosphorus recommended for buildup over a 4-year period for various soil-test levels is presented in Table 55.

Because the rate of 9 pounds of P_2O_5 to increase the soil test 1 pound is an average for Illinois soils, some soils will fail to reach the desired goal in 4 years with P_2O_5 applied at this rate, and others will exceed the goal. Therefore, it is recommended that each field be retested every 4 years.

In addition to the supplying power of the soil, the optimum soil-test value also is influenced by the crop to be grown. For example, the phosphorus soil-test level required for optimum yields of wheat and oats (Figure 17) is considerably higher than that required for corn and soybean yields, partly because wheat and corn have different phosphorus uptake patterns. Wheat requires a large amount of readily available phosphorus in the fall, when the root system is feeding primarily from the upper soil surface. Phosphorus is taken up by corn until the grain is fully developed, so subsoil phosphorus is more important in interpreting the phosphorus test for corn than for wheat. To compensate for the higher phosphorus requirements of wheat and oats, it is suggested that 1.5 times the amount of expected phosphorus removal be applied prior to seeding these crops.

This correction has already been included in the maintenance values listed for wheat and oats in Table 56.

Maintenance. In addition to adding fertilizer to build up the soil test, sufficient fertilizer should be added each year to maintain a specified soil-test level. The amount of fertilizer required to maintain the soil-test value is equal to the amount removed by the harvested portion of the crop (Table 56). The only exception to this guideline is that the maintenance value for wheat and oats is equal to 1.5 times the amount of phosphorus (P_2O_5) removed by the grain. This correction has already been accounted for in the maintenance values given in Table 56.

Potassium

As indicated, phosphorus will usually remain in the soil unless it is removed by a growing crop or by erosion; thus soil levels can be built up as described. Experience in the last several years indicates that on most soils potassium tends to follow the buildup pattern of phosphorus, but on other soils, soil-test levels do not build up as expected. Because of this,

Table 56. Maintenance Fertilizer Required for Various Yields of Crops

Yield, bushels or tons per acre	P_2O_5	K_2O[a]
	pounds per acre	
Corn grain		
90 bu	39	25
100	43	28
110	47	31
120	52	34
130	56	36
140	60	39
150	64	42
160	69	45
170	73	48
180	77	50
190	82	53
200	86	56
Oats		
50 bu	19[b]	10
60	23	12
70	27	14
80	30	16
90	34	18
100	38	20
110	42	22
120	46	24
130	49	26
140	53	28
150	57	30
Soybeans		
30 bu	26	39
40	34	52
50	42	65
60	51	78
70	60	91
80	68	104
90	76	117
100	85	130
Corn silage		
90 bu; 18T	48	126
100; 20	53	140
110; 22	58	154
120; 24	64	168
130; 26	69	182
140; 28	74	196
150; 30	80	210
Wheat		
30 bu	27[b]	9
40	36	12
50	45	15
60	54	18
70	63	21
80	72	24
90	81	27
100	90	30
110	99	33
Alfalfa, grass, or alfalfa-grass mixtures		
2T	24	100
3	36	150
4	48	200
5	60	250
6	72	300
7	84	350
8	96	400
9	108	450
10	120	500

[a] If the annual application option is chosen, then K application will be 1.5 times the values shown below.
[b] Values given are 1.5 times actual removal. (See page 56.)

both the buildup-maintenance and the annual application options are provided.

Producers who have one or more of the following conditions should consider the annual application option:

1. Soils for which past records indicate that soil-test potassium does not increase when buildup applications are applied.
2. Sandy soils that do not have a capacity large enough to hold adequate amounts of potassium.
3. Producers who have an unknown or very short tenure arrangement.

On all other fields, use of the buildup-maintenance option is suggested.

Rate of Fertilizer Application

Buildup. The only significant loss of soil-applied potassium is through crop removal or soil erosion. Therefore, it is recommended that soil-test potassium be built up to values of 260 and 300 pounds of exchangeable potassium, respectively, for soils in the low and high cation-exchange capacity region. These values are slightly higher than that required for maximum yield, but as in the recommendations for phosphorus, this will ensure that potassium availability will not limit crop yields (Figure 18).

Research has shown that 4 pounds of K_2O are required, on the average, to increase the soil test 1 pound. Therefore, the recommended rate of potassium application for increasing the soil-test value to the desired goal is equal to four times the difference between the soil-test goal and the actual soil-test value.

Tests on soil samples that are taken before May 1 or after September 30 should be adjusted downward as follows: subtract 30 for the dark-colored soils in central and northern Illinois; subtract 45 for the light-colored soils in central and northern Illinois; subtract 60 for the medium- and light-colored soils in southern Illinois; and subtract 45 for the fine-textured bottomland soils. Annual buildup rates of potassium application recommended for a 4-year period for various soil test values are presented in Table 57.

Wheat is not very responsive to potassium unless the soil test is less than 100. Because wheat is usually grown in rotation with corn and soybeans, however, it is suggested that soils be maintained at the optimum available potassium level for corn and soybeans.

Maintenance. As with phosphorus, the amount of fertilizer required to maintain the soil-test value equals the amount removed by the harvested portion of the crop (Table 56).

Annual application option. If soil-test levels are below the desired buildup goal, apply potassium fertilizer annually at an amount equivalent to 1.5 times the potassium content in the harvested portion of the expected yield. If levels are only slightly below desired buildup levels, so that buildup and maintenance are less than 1.5 times removal, add the lesser amount.

Table 57. Amount of Potassium (K_2O) Required To Build Up the Soil (based on the buildup occurring over a four-year period; 4 pounds of K_2O per acre required to change the K test 1 pound)

K test[a], pounds per acre	Amount of K_2O to apply per acre *each year* for soils with cation exchange capacity: Low[b]	High[b]
50	210	250
60	200	240
70	190	230
80	180	220
90	170	210
100	160	200
110	150	190
120	140	180
130	130	170
140	120	160
150	110	150
160	100	140
170	90	130
180	80	120
190	70	110
200	60	100
210	50	90
220	40	80
230	30	70
240	20	60
250	10	50
260	0	40
270	0	30
280	0	20
290	0	10
300	0	0

[a] Tests on soil samples that are taken before May 1 or after September 30 should be adjusted downward as follows: subtract 30 pounds for dark-colored soils in central and northern Illinois; 45 pounds for light-colored soils in central and northern Illinois, and fine-textured bottomland soils; and 60 pounds for medium- and light-colored soils in southern Illinois.

[b] Low cation-exchange capacity soils are those with CEC less than 12 meq./100 g soil; high capacity soils are those with CEC at least 12 meq./100 g soil.

Continue to monitor the soil-test potassium level every 4 years.

If soil-test levels are within a range from the desired goal to 100 pounds above the desired potassium goal, apply enough potassium fertilizer to replace what the harvested yield will remove.

Each of the proposed options (buildup-maintenance and annual) has advantages and disadvantages. In the short run, the annual option will likely be less costly. In the long run, the buildup approach may be more economical. In years of high income, tax benefits may be obtained by applying high rates of fertilizer. Also, in periods of low fertilizer prices, the soil can be built to higher levels that in essence bank the materials in the soil for use at a later date when the economy may not be as good for fertilizer purchases. Producers using the buildup system are insured against yield loss that may occur in years when weather conditions prevent fertilizer application or in years when fertilizer supplies are not adequate. The primary advantage of the buildup concept is the slightly lower risk of potential yield reduction that may result from lower annual fertilizer rates. This is especially true in years of exceptionally favorable growing conditions. The primary disadvantage of the buildup option is the high cost of fertilizer in the initial buildup years.

Examples of how to figure phosphorus and potassium fertilizer recommendations follow.

Example 1. Continuous corn with a yield goal of 140 bushels per acre:

(a)

Soil-test results	*Soil region*
P_1 30	high
K 250	high

(b) *Fertilizer recommendation, pounds per acre per year*

	P_2O_5	K_2O
Buildup	22 (Table 55)	50 (Table 57)
Maintenance	60 (Table 56)	39 (Table 56)
Total	82	89

Example 2. Corn-soybean rotation with a yield goal of 140 bushels per acre for corn and 40 bushels per acre for soybeans:

(a)

Soil-test results	*Soil region*
P_1 20	low
K 200	low

(b) *Fertilizer recommendation, pounds per acre per year*

	P_2O_5	K_2O
	Corn	
Buildup	68	60
Maintenance	60	39
Total	128	99
	Soybeans	
Buildup	68	60
Maintenance	34	52
Total	102	112

Note that buildup recommendations are independent of the crop to be grown, but maintenance recommendations are directly related to the crop to be grown and the yield goal for the particular crop.

Example 3. Continuous corn with a yield goal of 150 bushels per acre:

(a)

Soil-test results	*Soil region*
P_1 90	low
K 420	low

(b) *Fertilizer recommendation, pounds per acre per year*

	P_2O_5	K_2O
Buildup	0	0
Maintenance	0	0
Total	0	0

Note that soil-test values are higher than those

suggested; thus no fertilizer is recommended. Retest the soil after 4 years to determine fertility needs.

Example 4. Corn-soybean rotation with a yield goal of 120 bushels per acre for corn and 35 bushels per acre for soybeans:

(a)

Soil-test results	*Soil region*
P_1 20	low
K 180	low (soil test does not increase as expected)

(b) *Fertilizer recommendation, pounds per acre per year*

	P_2O_5	K_2O
	Corn	
Buildup	68	—
Maintenance	52	—
Total	120	51 (34 x 1.5)
	Soybeans	
Buildup	68	—
Maintenance	30	—
Total	98	69 (46 x 1.5)

For farmers planning to double-crop soybeans after wheat, it is suggested that phosphorus and potassium fertilizer required for both the wheat and soybeans be applied before seeding the wheat. This practice will reduce the number of field operations necessary at planting time and will hasten the planting operation.

The maintenance recommendations for phosphorus and potassium in a double-crop wheat and soybean system are presented in Tables 58 and 59, respectively.

Table 58. Maintenance Phosphorus Required for Wheat-Soybean Double-Crop System

Wheat yield, bu/acre	Soybean yield, bu/acre				
	20	30	40	50	60
	P_2O_5, *lb/acre*				
30	44	53	61	69	78
40	53	62	70	78	87
50	62	71	79	87	96
60	71	80	88	96	105
70	80	89	97	105	114
80	89	98	106	114	123

Table 59. Maintenance Potassium Required for Wheat-Soybean Double-Crop System

Wheat yield, bu/acre	Soybean yield, bu/acre				
	20	30	40	50	60
	K_2O, *lb/acre*				
30	35	48	61	74	87
40	38	51	64	77	90
50	41	54	67	80	93
60	44	57	70	83	96
70	47	60	73	86	99
80	50	63	76	89	102

Assuming a wheat yield of 50 bushels per acre followed by a soybean yield of 30 bushels per acre, the maintenance recommendation would be 71 pounds of P_2O_5 and 54 pounds of K_2O per acre.

Computerized recommendations

Soil fertility recommendations have been incorporated into a microcomputer program that utilizes the soil-test information, soil type and characteristics, cropping and management history, cropping plans and yield goals to develop recommendations for lime, nitrogen, phosphorus, and potassium. This program, called *Soil Plan*, groups together similar fertilizer recommendations and provides a map showing where each recommendation should be implemented within the field. Users have the option of altering the map to adjust to the kind of spread pattern desired. Additionally, the user can change the different variables to determine their impact on fertilizer needed.

Further information about this program may be obtained from the Office of Computer Coordinator, 123 Mumford Hall, 1301 West Gregory, Urbana, Illinois 61801.

Time of application

Although the fertilizer rates for buildup and maintenance in Tables 55 and 57 are for an annual application, producers may apply enough nutrients in any one year to meet the needs of the crops to be grown in the succeeding 2- to 3-year period.

Phosphorus and potassium fertilizers may be applied in the fall to fields that will not be fall tilled, provided that the slope is less than 5 percent. Do not fall-apply fertilizer to fields that are subject to rapid runoff. When the probability of runoff loss is low, soybean stubble need not be tilled solely for the purpose of incorporating fertilizer. This statement holds true when ammoniated phosphate materials are used as well because the potential for volatilization of nitrogen from ammoniated phosphate materials is insignificant.

For perennial forage crops, broadcast and incorporate all of the buildup and as much of the maintenance phosphorus as economically feasible before seeding. On soils with low fertility, apply 30 pounds of phosphate (P_2O_5) per acre using a band seeder. If a band seeder is used, you may safely apply a maximum of 30 to 40 pounds of potash (K_2O) per acre in the band with the phosphorus. Up to 600 pounds of K_2O per acre can be safely broadcast in the seedbed without damaging seedlings.

Applications of phosphorus and potassium top-dressed on perennial forage crops may be made at any convenient time. Usually this will be after the first harvest or in September.

High water-solubility of phosphorus

The water-solubility of the P_2O_5 listed as available on the fertilizer label is of little importance under

typical field crop and soil conditions on soils with medium to high levels of available phosphorus, when recommended rates of application and broadcast placement are used.

For some situations, water-solubility is important. These situations include the following:

1. For band placement of a small amount of fertilizer to stimulate early growth, at least 40 percent of the phosphorus should be water-soluble for application to acidic soils and, preferably, 80 percent for calcareous soils. As shown in Table 60, the phosphorus in nearly all fertilizers commonly sold in Illinois is highly water-soluble. Phosphate water solubility in excess of 80 percent has not been shown to give further yield increases above those that have water-solubility levels of at least 50 percent.
2. For calcareous soils, a high degree of water solubility is desirable, especially on soils that are shown by soil test to be low in available phosphorus.

Secondary nutrients

The elements that are classified as secondary nutrients include calcium, magnesium, and sulfur. Crop yield response to application of these three nutrients has been observed on only a very limited basis in Illinois. Therefore, the data base necessary to correlate and calibrate soil-test procedures is very limited, and thus the reliability of the suggested soil-test levels for the secondary nutrients presented in Table 61 is low.

Deficiency of calcium has not been recognized in Illinois where soil pH is 5.5 or above. Calcium deficiency associated with acidic soils should be corrected by the use of limestone that is adequate to correct the soil pH.

Magnesium deficiency has been recognized in isolated situations in Illinois. Although the deficiency is usually associated with acidic soils, in some instances low magnesium has been reported on sandy soils where the soils were not excessively acidic. The soils most likely to be deficient in magnesium include sandy soils throughout Illinois and low exchange-capacity soils of southern Illinois. Deficiency will be more likely where calcitic rather than dolomitic limestone has been used and where potassium test levels have been high (above 400).

Recognition of sulfur deficiency has been reported with increasing frequency throughout the Midwest. These deficiencies probably are occurring because of (1) increased use of S-free fertilizer, (2) decreased use of sulfur as a fungicide and insecticide, (3) increased crop yields, resulting in increased requirements for all of the essential plant nutrients, and (4) decreased atmospheric sulfur supply.

Organic matter is the primary source of sulfur in soils. Thus soils low in organic matter are more likely to be deficient than are soils with a high level of organic matter. Because sulfur is very mobile and can be readily leached, deficiency is more likely to be found on sandy soils than on finer-textured soils.

A yield response to sulfur application was observed at 5 of 85 locations in Illinois (Table 62). Two of these responding sites, one an eroded silt loam and one a sandy soil, were found in northwestern Illinois (Whiteside and Lee counties); one site, a silty clay loam, was in central Illinois (Sangamon County); and two sites, one a silt loam and one a sandy loam soil, were in southern Illinois (Richland and White counties).

At the responding sites, sulfur treatments resulted in corn yields that averaged 11.2 bushels per acre more than yields from the untreated plots. At the nonresponding sites, yields from the sulfur-treated plots averaged only 0.5 bushel per acre more than those from the untreated plots (Table 62). If one considers only the responding sites, the sulfur soil test predicts with good reliability which sites will respond to sulfur applications. Of the five responding sites,

Table 60. Characteristics of Some Common Processed-Phosphate Materials

Material	Percent P_2O_5	Percent water-soluble	Percent citrate-soluble	Total pct. available
Ordinary superphosphate 0-20-0	16-22	78	18	96
Triple superphosphate	44-47	84	13	97
Mono-ammonium phosphate 11-48-0	46-48	100	..	100
Diammonium phosphate 18-46-0	46	100	..	100
Ammonium polyphosphate 10-34-0, 11-37-0	34-37	100	..	100

Table 61. Suggested Soil-Test Levels for the Secondary Nutrients

Soil type	Levels that are adequate for crop production: Calcium	Magnesium	Rating	Sulfur
	pounds per acre			*lb/acre*
Sandy	400	60-75	Very low	0-12
Silt loam	800	150-200	Low	12-22
			Response unlikely	22

Table 62. Average Yields at Responding and Nonresponding Zinc and Sulfur Test Sites, 1977-79

	Number of sites	Yield from untreated plots	Yield from zinc-treated plots	Yield from sulfur-treated plots
		bushels per acre		
Responding sites				
Low-sulfur soil	5	140.0	...	151.2
Low-zinc soil	3	150.6	164.7	...
Nonresponding sites	80	147.6	146.2	148.2

one had only 12 pounds of sulfur per acre, less than the amount considered necessary for normal plant growth, and three had marginal sulfur concentration (from 12 to 20 pounds of sulfur per acre). Sulfur tests on the 80 nonresponding sites showed 14 to be deficient and 29 to have a level of sulfur that is considered marginal for normal plant growth. Sulfur applications, however, produced no significant positive response in these plots. The correlation between yield increases and measured sulfur levels in the soil was very low, indicating that the sulfur soil test did not reliably predict sulfur need.

In addition to soil-test values, one should also consider organic-matter level, potential atmospheric sulfur contributions, subsoil sulfur content, and moisture conditions just before soil sampling in determining whether a sulfur response is likely. If organic-matter levels are greater than 2.5 percent or if the field in question is located in an area downwind from industrial operations where significant amounts of sulfur are being emitted, use sulfur only on a trial basis even when the soil-test reading is low. Because sulfur is a mobile nutrient supplied principally by organic-matter oxidation, abnormal precipitation (either high or low) could adversely affect the sulfur status of samples taken from the soil surface. If precipitation has been high just before sampling, some samples may have a low reading due to leaching. If precipitation were low and temperatures warm, some soils may have a high reading when, in fact, the soil is not capable of supplying adequate amounts of sulfur throughout the growing season.

Micronutrients

The elements that are classified as essential micronutrients include zinc, iron, manganese, copper, boron, molybdenum, and chlorine. These nutrients are classified as micronutrients because they are required in small (micro) amounts. Confirmed deficiencies of these micronutrients in Illinois have been limited to boron deficiency of alfalfa, zinc deficiency of corn, and iron and manganese deficiencies of soybeans.

Similar to the tests for secondary nutrients, the reliability and usefulness of micronutrient tests are very low because of the limited data base available to correlate and calibrate the tests. Suggested levels for each of the tests are provided in Table 63. In most cases, use of plant analysis will probably provide a better estimate of micronutrient needs than will the soil test.

Manganese deficiency (stunted plants with green veins in yellow or whitish leaves) is common on high-pH (alkaline), sandy soils, especially during cool, wet weather in late May and June. Suggested treatment is to spray either manganese sulfate or an organic manganese formulation onto the leaves soon after the symptoms first appear; use the rate suggested by the manufacturer. Broadcast application on the soil is ineffective because the manganese becomes unavailable in soils with a high pH.

Table 63. Suggested Soil-Test Levels for Micronutrients

Micronutrient	Soil-test level		
	Very low	Low	Adequate
		pounds per acre	
Boron (hot-water soluble)	0.5	1.0	2.0
Iron (DTPA)	..	<4.0	>4.0
Manganese (DTPA)	..	<2.0	>2.0
Manganese (H_3PO_4)	..	<10	>10
Zinc (.1N HCl)	..	<7.0	>7.0
Zinc (DTPA)	..	<1.0	>1.0

Wayne and Hark soybean varieties or lines developed from them often show iron deficiency on soils with a very high pH (usually 7.4 to 8.0). The symptoms are similar to those shown with manganese deficiency. Most of the observed deficiencies have been on Harpster, a "shelly" soil that occurs in low spots in some fields in central and northern Illinois. This problem has appeared on Illinois farms only since the Wayne variety was introduced in 1964.

Soybeans often outgrow the stunted, yellow appearance of iron shortage. As a result, it has been difficult to measure yield losses or decide whether or how to treat affected areas. Sampling by United States Department of Agriculture (USDA) scientists in 1967 indicated yield reductions of 30 to 50 percent in the center of severely affected spots. The yield loss may have been caused by other soil factors associated with a very high pH and poor drainage, rather than by iron deficiency itself. Several iron treatments were ineffective in trials near Champaign and DeKalb in 1968.

Research in Minnesota has shown that time of iron application is critical if a response is to be attained. Researchers recommend that a rate of 0.15 pound of iron per acre as iron chelate be applied to leaves within 3 to 7 days after chlorosis symptoms develop (usually in the second-trifoliate stage of growth). Waiting for soybeans to grow to the fourth- or fifth-trifoliate stage before applying iron resulted in no yield increase. Because iron applied to the soil surface between rows does not help, directed applications directly over the soybean plants were preferred.

A significant yield response to zinc applications was observed at 3 of 85 sites evaluated in Illinois (Table 62). The use of zinc at the responding sites produced a corn yield that averaged 14.1 bushels per acre more than the check plots. Two sites were Fayette silt loams in Whiteside County, and one was a Greenriver sand in Lee County.

At two of the three responding sites, tests showed that the soil was low or marginal in available zinc. The soil of the third had a very high zinc level but was deficient in available zinc, probably because of the excessively high phosphorus level also found at that site.

The zinc soil-test procedures accurately predicted

results for two-thirds of the responding sites. The same tests, however, incorrectly predicted that 19 other sites would also respond. These results suggest that the soil test for available zinc can indicate where zinc deficiencies are found but does not indicate reliably whether the addition of zinc will increase yields.

To identify areas before micronutrient deficiencies become important, continually observe the most sensitive crops in soil situations in which the elements are likely to be deficient (Table 64).

In general, deficiencies of most micronutrients are accentuated by one of five situations: (1) strongly weathered soils, (2) coarse-textured soils, (3) high-pH soils, (4) organic soils, and (5) soils that are inherently low in organic matter or low in organic matter because erosion or land-shaping processes have removed topsoil.

The use of micronutrient fertilizers should be limited to the application of specific micronutrients to areas of known deficiency. Only the deficient nutrient should be applied. An exception to this guideline would be situations in which farmers already in the highest yield bracket try micronutrients on an experimental basis in fields that are yielding less than would be expected under good management, which includes an adequate nitrogen, phosphorus, and potassium fertility program and a favorable pH.

Method of fertilizer application

With the advent of new equipment, producers have a number of options for placement of fertilizers. These options range from traditional broadcast application to injection of the materials at varying depths in the soil. Selection of the proper application technique for a particular field will depend at least in part upon the inherent fertility level, the crop to be grown, the land tenure, and the tillage system.

On fields where the fertility level is at or above the desired goal, there is little research evidence to show any significant difference in yield that is associated with method of application. In contrast, on low-testing soils and in soils that "fix" phosphorus, placement of the fertilizer within a concentrated band has been shown to result in higher yields, particularly at low rates of application. On higher testing soils, plant recovery of applied fertilizer in the year of application will usually be greater from a band than a broadcast application although yield differences are unlikely.

Broadcast fertilization. On highly fertile soils, both maintenance and buildup phosphorus and potassium will be efficiently utilized when broadcast and plowed or disked in. This system, particularly when the tillage system includes a moldboard plow every few years, distributes nutrients uniformly throughout the entire plow depth. As a result, roots growing within that zone have access to high levels of fertility. Because the nutrients are intimately mixed with a large volume of soil, opportunity exists for increased nutrient fixation on soils having a high fixation ability. Fortunately, most Illinois soils do not have high fixation rates for phosphorus or potassium.

Row fertilization. On soils of low fertility, placement of fertilizer in a concentrated band below and to the side of the seed has been shown to be an efficient method of application, especially in situations

Table 64. Soil Situations and Crops Susceptible to Micronutrient Deficiency

Micronutrient	Sensitive crop	Susceptible soil situations	Season favoring deficiency
Zinc (Zn)	Young corn	1. Low in organic matter, either inherently or because of erosion or land shaping 2. High pH, that is, >7.3 3. Very high phosphorus 4. Restricted root zone 5. Coarse-textured (sandy) soils 6. Organic soils	Cool, wet
Iron (Fe)	Wayne soybeans, grain sorghum	High pH	Cool, wet
Manganese (Mn)	Soybeans, oats	1. High pH 2. Restricted root zone 3. Organic soils	Cool, wet
Boron (B)	Alfalfa	1. Low organic matter 2. High pH 3. Strongly weathered soils in south-central Illinois 4. Coarse-textured (sandy) soils	Drought
Copper (Cu)	Corn, wheat	1. Infertile sand 2. Organic soils	Unknown
Molybdenum (Mo)	Soybeans	Strongly weathered soils in south-central Illinois	Unknown
Chlorine (Cl)	Unknown	Coarse-textured soils	Excessive leaching by low-Cl water

for which the rate of application is markedly less than that needed to build the soil to the desired level. Producers who are not assured of having long-term tenure on the land may wish to consider this option. The major disadvantages of this technique are (1) the additional time and labor required at planting time, (2) limited contact between roots and fertilizer, and (3) inadequate rate of application to increase soil levels for future crops.

Strip application. With this technique, phosphorus, potassium, or both are applied in narrow bands on approximately 30-inch centers on the soil surface, in the same direction as the primary tillage. The theory behind this technique is that, after moldboard plowing, the fertilizer will be distributed in a narrow vertical band throughout the plow zone. Use of this system reduces the amount of soil-to-fertilizer contact as compared with a broadcast application, and thus it reduces the potential for nutrient fixation. Because the fertilizer is distributed through a larger soil volume than with a band application, the opportunity for root-fertilizer contact is greater.

Deep fertilizer placement. Several terms have been used to define this technique. They include root-zone banding, dual placement, knife injection, and deep placement. With this system a mixture of N-P or N-P-K is injected at a depth ranging from 4 to 8 inches. The knife spacings used may vary by crop to be grown, but generally they are 15 to 18 inches apart for close-grown crops such as wheat and 30 inches for row crops. Use of this technique provided a significantly higher wheat yield as compared with a broadcast application of the same rate of nutrients in some, but not all, experiments conducted in Kansas. Wisconsin research showed the effect of this technique to be equivalent to that of a band application for corn on a soil testing high in phosphorus but inferior to that of a band application for corn on a soil testing low in phosphorus. If this system is used on low-testing soils, it is advisable to apply a portion of the phosphorus fertilizer in a band with the planter.

Dribble fertilizer. This technique involves the application of urea-ammonium nitrate solutions in concentrated bands on 30-inch spacings on the soil surface. Results from several states have shown that this system reduces the potential for nitrogen loss of these materials, as compared with an unincorporated broadcast application. However, it has not been shown to be superior to an injected or an incorporated application of urea-ammonium nitrate solution.

"Pop-up" fertilization. The term "pop-up" is a misnomer. The corn does not emerge sooner than it does without this kind of application, and it may come up 1 or 2 days later. The corn may, however, grow more rapidly during the first 1 to 2 weeks after emergence. Pop-up fertilizer will make corn look very good early in the season and may aid in early cultivation for weed control. But no substantial difference in yield is likely in most years due to a pop-up application as compared to fertilizer that is placed in a band to the side and below the seed. Seldom will there be a difference of more than a few days in the time the root system intercepts fertilizer placed with the seed as compared to that placed below and to the side of the seed.

If used, pop-up fertilizer should contain all three major nutrients in a ratio of about 1-4-2 of N-P_2O_5-K_2O (1-1.7-1.7 of N-P-K). Under normal moisture conditions, the maximum safe amount of N plus K_2O for pop-up placement is about 10 or 12 pounds per acre in 40-inch rows and correspondingly more in 30- and 20-inch rows. In excessively dry springs, even these low rates may result in damage to seedlings, reduction in germination, or both. Pop-up fertilizer is unsafe for soybeans. In research conducted at Dixon Springs, a stand was reduced to one-half by applying 50 pounds of 7-28-14 and reduced to one-fifth with 100 pounds of 7-28-14.

Foliar fertilization. Researchers have known for many years that plant leaves absorb and utilize nutrients sprayed on them. Foliar fertilization has been used successfully for certain crops and nutrients. This method of application has had the greatest use with nutrients required in only small amounts by plants. Nutrients required in large amounts, such as nitrogen, phosphorus, and potassium, have usually been applied to the soil rather than the foliage.

The possible benefit of foliarly applied nitrogen fertilizer was researched at the University of Illinois in the 1950s. Foliarly applied nitrogen increased corn and wheat yield, provided that the soil was deficient in nitrogen. Where adequate nitrogen was applied to the soil, additional yield increases were not obtained from foliar fertilization.

Additional research in Illinois was conducted on foliar application of nitrogen to soybeans in the 1960s. This effort was an attempt to supply additional nitrogen to soybeans without decreasing nitrogen symbiotically fixed. That is, it was thought that if nitrogen application were delayed until after nodules were well established, then perhaps symbiotic fixation would remain active. Single or multiple applications of nitrogen solution to foliage did not increase soybean yields. Damage to vegetation occurred in some cases because of leaf "burn" caused by the nitrogen fertilizer.

Although considerable research in foliar fertilization had been conducted in Illinois already, new research was conducted in 1976 and 1977. This new research was prompted by a report from a neighboring state indicating that soybean yields had recently been increased by as much as 20 bushels per acre in some trials. Research in that state differed from earlier work on soybeans in that, in addition to nitrogen, the foliar fertilizer increased yield only if phosphorus, potassium, and sulfur were also included. Researchers there thought that soybean leaves become deficient in nutrients as nutrients are translocated from vegetative parts to the grain during grain development. They

reasoned that foliar fertilization, which would prevent leaf deficiencies, should result in increased photosynthesis that would be expressed in higher grain yields.

Foliar fertilization research was conducted at several locations in Illinois during 1976 and 1977 — ranging from Dixon Springs in southern Illinois to DeKalb in northern Illinois. None of the experiments gave economical yield increases. In some cases there were yield reductions, which were attributed to leaf damage caused by the fertilizer. Table 65 contains data from a study at Urbana in which soybeans were sprayed four times with various fertilizer solutions. Yields were not increased by foliar fertilization.

Table 65. Yields of Corsoy and Amsoy Soybeans After Fertilizer Treatments Were Sprayed on the Foliage Four Times, Urbana

Treatment per spraying, lb/acre				Yield, bu/acre	
N	P_2O_5	K_2O	S	Corsoy	Amsoy
0	0	0	0	61	56
20	0	0	0	54	53
0	5	8	1	58	56
10	5	8	1	56	58
20	5	8	1	55	52
30	7.5	12	1.5	52	46

Nontraditional products

In this day of better informed farmers, it seems hard to believe that the number of letters, calls, and promotional leaflets about nontraditional products is increasing. The claim made is usually that "Product X" either replaces fertilizers and costs less, makes nutrients in the soil more available, supplies micronutrients, or is a natural product that does not contain strong acids that kill soil bacteria and earthworms.

The strongest position that legitimate fertilizer dealers, Extension advisers, and agronomists can take is to challenge these peddlers to produce unbiased research results in support of their claims. Testimonials by farmers are no substitute for research.

Extension specialists at the University of Illinois are ready to give unbiased advice when asked about purchasing new products or accepting a sales agency for them.

In addition, each county Extension office has the publication *Compendium of Research Reports on the Use of Nontraditional Materials for Crop Production*, which contains data on a number of nontraditional products that have been tested in the Midwest. Check with your local Extension office for this information.

Soil Management and Tillage Systems

Selecting the most suitable tillage system for a particular farming situation is an important management decision. Intensive use of a moldboard plow, disk, harrow, and cultivator was once the only practical tillage system that could assure crop producers of both establishing a crop and controlling weeds. With a wide variety of herbicides and tillage and planting implements now available, producers have an opportunity to select a tillage system for their specific soil, crop, and climatic conditions. When selecting a tillage system, evaluate the various systems as they relate to soil type, slope, erosion control, drainage, moisture, temperature, timeliness, fertilizer distribution, and the potential of each for controlling weeds, insects, and disease. No single tillage system is clearly superior to the others for the wide array of soil, crop, and climatic conditions that occur in Illinois.

The following five sections describe tillage systems used in Illinois and list some advantages and disadvantages for each.

Moldboard plow system (conventional clean tillage)

Primary tillage is done with a moldboard plow. Secondary tillage includes one or more operations with a disk field cultivator, harrow, or similar implement.

Advantages

1. The uniform, fine seedbed gives good seed-soil contact and makes for easy planting.
2. Survival of some insects, especially the European corn borer, is reduced because cornstalk residues are buried.
3. The system is flexible and adaptable to a wide range of soil and crop conditions.
4. Use of labor and machinery is reasonably well distributed with fall plowing.
5. Yields are as high as or higher than with alternative tillage systems over a wide range of soil and weather conditions.

Disadvantages

1. Bare soil is very susceptible to wind and water erosion.
2. A uniform, fine seedbed is more susceptible to crusting.
3. Fuel consumption, labor inputs, and machinery costs are high.

Chisel plow system

Primary tillage is usually done in the fall with a chisel plow, followed by use of a disk or field cultivator in the spring.

Advantages

1. Machinery costs and time are slightly less than with moldboard plowing.
2. The soil surface is rough and partially covered by crop residues that reduce raindrop impact and runoff.
3. Soil roughness and residues protect the soil from water and wind erosion. This benefit may be lost in the spring if tillage is excessive.
4. Yields are comparable to other tillage systems, especially on well-drained soils.

Disadvantages

1. In heavy residue, a heavy planter with disk openers and a coulter in front of each row may be needed for planting.
2. The lower soil temperatures, especially on poorly drained soils, can retard early corn growth in the northern two-thirds of Illinois.
3. Stands are sometimes slightly lower than with clean tillage, although the newer planters may eliminate this problem.
4. Slightly higher herbicide rates may be necessary for satisfactory weed control.
5. Crop residue on the soil surface may harbor insects and disease-causing organisms.

Disk system

A heavy disk or a tandem disk harrow is used for primary tillage in the fall or spring. A field cultivator or a light disk is used for secondary tillage. Advantages and disadvantages of the chisel plow system also apply to the disk system, provided that the disk produces a rough soil surface covered with some crop residues.

Ridge-tillage system (till-plant)

The ridge-tillage system is a one-pass, tillage planting operation. Seed is planted in ridges formed during cultivation of the previous crop. A sweep or double-disk mounted in front of each planter unit pushes the top inch or so of crop residue from existing ridges between the rows.

Advantages

1. Soil roughness and residues protect the soil from wind erosion and raindrop impact.
2. In the spring, soil temperature is higher in the ridge and soil moisture is lower.
3. Machinery and, possibly, herbicide costs are lower than with other tillage systems.
4. Wheel traffic is restricted to inter-row areas, causing less compaction in the rows.

Disadvantages

1. Cultivation is required to rebuild ridges and is often necessary to control weeds.
2. Because herbicides cannot be incorporated, the selection is limited. Contact herbicides may be necessary for adequate weed control.
3. The wheel spacing of machinery should be modified to avoid driving on ridges.
4. Narrow-row soybeans or small grains are not practical planting options.
5. Forming ridges in soybeans during cultivation may result in pod heights so close to the ground that harvest losses are higher.
6. End rows are usually planted without ridges or are leveled with a disk before the entire field is harvested.

No-tillage system (zero-tillage)

Seed is planted in previously undisturbed soil by means of a special heavy planter equipped to plant through residue into firm soil. Fertilizers and pesticides must be applied to the soil surface or in the narrow, tilled area of the row. Weeds growing at planting time are killed with a contact herbicide. Equipment is available to apply anhydrous ammonia in no-till.

Advantages

1. Soil erosion is greatly reduced with no-till compared to other systems.
2. Power, labor, and fuel costs are also greatly reduced compared to other tillage systems.
3. The no-till planter is very adaptable to a wide range of soil and residue conditions.
4. Firm soil may aid harvest operations in a wet year, but tillage may be needed to offset soil compaction caused by wheel traffic.

Disadvantages

1. Low soil temperatures often delay emergence and cause slow early growth.
2. A special planter or planter attachments may be needed. Care should be exercised when planting to ensure adequate seed-soil contact and that planting depth and seed cover are as uniform as possible.
3. Rodents and birds may reduce stands.
4. Some insect and crop disease problems increase when crop residues are left on the soil surface.
5. Without cultivation, weed control is entirely dependent on herbicides.
6. Higher herbicide rates or more costly herbicide combinations may be needed for adequate weed control.

Soil erosion and residue management

Bare, smooth soil left by moldboard plowing and intensive secondary tillage is extremely susceptible to soil erosion. Many Illinois soils have subsurface layers that restrict root development. Soil erosion slowly but permanently removes the soil that is most favorable for crop growth, resulting in gradually decreasing soil productivity and value. Even on soils without root-restricting subsoils, erosion removes nutrients that

must be replaced with additional fertilizer to maintain yields.

Sediment from eroding fields increases water pollution, reduces the storage capacity of lakes and reservoirs, and decreases the efficiency of drainage systems. Effective erosion control systems usually include one or more of three features:

1. The soil is protected with a cover of vegetation, such as a mulch of crop residue.
2. The soil is tilled so that a maximum amount of water is absorbed with minimum runoff.
3. Long slopes are divided into a series of short slopes so that the water cannot get "running room."

Chisel plow, disk, ridge-till, and no-till systems may be classified as conservation tillage if a minimum residue cover of 20 to 30 percent remains on the soil surface after planting (Figure 19). This minimum amount of residue cover reduces erosion by approximately 50 percent over cleanly tilled fields. A 20 to 30 percent residue cover should be maintained during the critical erosion period from early spring until the crop canopy is established. The amount of residue cover remaining on the soil surface after a single pass of tillage and planting implements can vary considerably (Table 66). In addition, soil type and moisture content, operating speed and depth, amount and condition of residue, sequence of tillage events, and crop yields all affect the amount of residue left. With conservation tillage, the attachments used on an implement and the method of operation can be as important as the selection of the implement itself in retaining crop residue. Refer to the Cooperative Extension fact sheet entitled *The Residue Dimension*, by R. Walker and others, for methods to estimate residue cover.

The effectiveness of conservation tillage systems in reducing soil erosion on an 8- to 12-percent slope in simulated rainfall tests on Tama silt loam at Perry, Illinois, is illustrated in Figures 20 and 21. Nearly 1.2 tons of soil per acre were eroded from an area that had been moldboard-plowed, planted on the contour, and subjected to 2.4 inches of intense rain (Figure 20). Under similar rainfall conditions, areas that were chisel-plowed and no-tilled following corn lost about 0.4 and 0.2 tons of soil per acre, respectively.

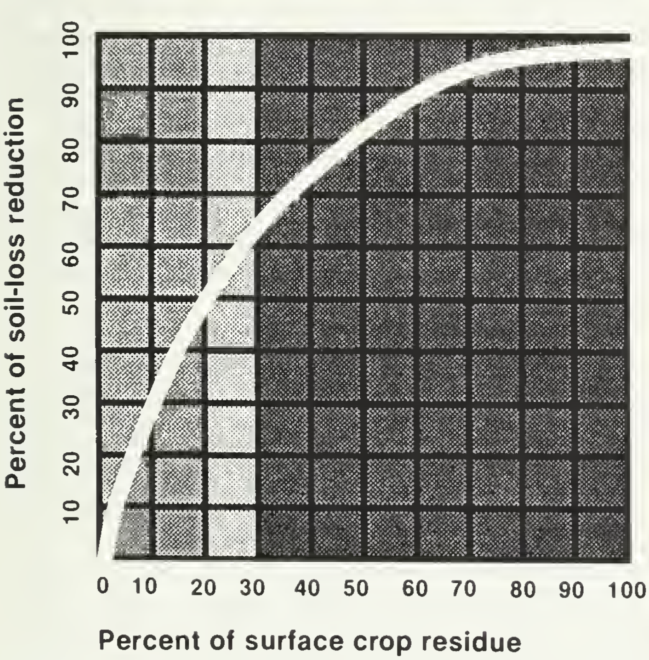


Figure 19. Percent of soil-loss reduction for various amounts of surface crop residue.

Table 66. Influence of Field Operations on Surface Residue

Tillage and planting implements	Percentage[a] of residue remaining after each operation
Moldboard plow	3 to 5
Chisel plow,	
Straight shovel points	50 to 75
Twisted shovel points	30 to 60
Anhydrous applicator	50 to 80
Disk (tandem or offset),	
3 inches deep	40 to 70
6 inches deep	30 to 60
Field cultivator	50 to 80
Planters,	
No coulter or smooth coulter	90 to 95
Narrow-ripple coulter (less than 1.5″ flutes)	85 to 90
Wide-fluted coulter (greater than 1.5″ flutes)	80 to 85
Sweeps or double disk furrowers (till-plant)	60 to 80
Drills,	
Disk openers	90 to 95
Hoe openers	50 to 80
Winter weathering	70 to 90

[a] Use lower values for fragile residue such as soybeans.

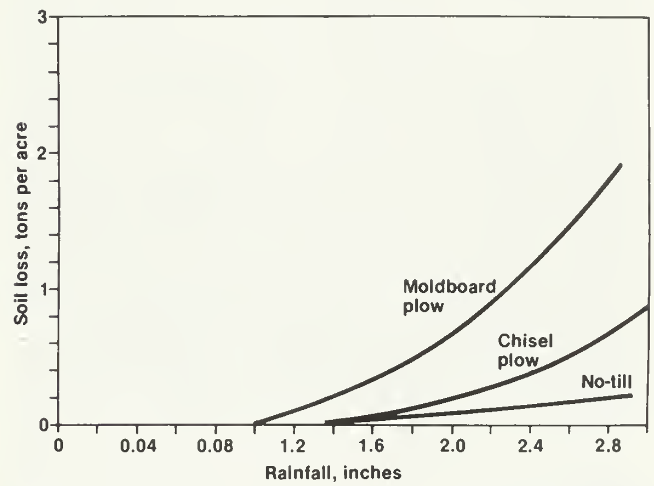


Figure 20. Soil loss after planting soybeans into corn residue on Tama silt loam, 8- to 12-percent slope, on contour.

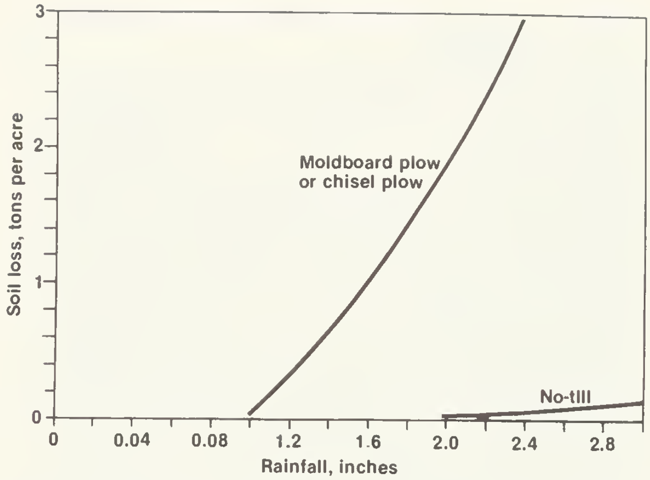


Figure 21. Soil loss after planting corn into soybean residue on Tama silt loam, 8- to 12-percent slope, on contour.

Soil erosion after soybeans is very difficult to control with most tillage systems because only a small amount of residue is produced. Soil loss was about 3 tons per acre for both moldboard- and chisel-plowed areas that were planted on the contour and subjected to 2.4 inches of intense rain (Figure 21). Soil erosion in the no-till area was reduced to 0.10 tons of soil per acre under similar rainfall conditions. No-till was the most effective tillage system in controlling soil erosion following soybeans.

Nevertheless, conservation tillage will not completely control water erosion on all soils. On sloping soils, contouring is necessary for all tillage systems. Chisel plows, for example, often leave shallow furrows that can concentrate rainwater and erode severely if the tillage direction is uphill and down. Long or steep slopes may also require terraces or other practices. For technical assistance in developing erosion control systems, consult your district conservationist or the Soil Conservation Service.

Water runoff

Immediately after operations like moldboard plowing, chisel plowing, and subsoiling, large amounts of rain can initiate runoff. After several rains, the soil surface often becomes sealed and runoff increases. Runoff is especially high when the soil surface is smooth in the spring after secondary tillage operations. Surface residue slows the velocity of water runoff.

Crop production with conservation tillage

Crop germination, emergence, and growth are largely regulated by soil temperature, moisture content, and nutrient placement. Tillage practices influence each of these components of the soil environment. Conservation tillage systems differ from conventional clean tillage in several respects.

Soil temperature. Crop residue on the soil surface insulates the soil from the sun's energy. In the spring, higher than normal soil temperatures are desirable for plant growth. Later in the season, cooler than normal temperatures are desirable, but a complete crop canopy at that time restricts the influence of crop residue on soil temperature.

Minimum soil temperatures occur between 6 and 8 a.m., and they are affected very little by tillage or crop residue. Maximum soil temperatures at a depth of 4 inches occur between 3 and 5 p.m. During May, fields tilled by the fall-plow method have soil temperatures 3° to 5°F warmer than those with a cornstalk mulch.

Tillage affects soil temperature most from late April until the crop forms a canopy that shades the soil surface. During May and early June, the reduced soil temperatures caused by a mulch are accompanied by slower growth of corn and soybeans. Whether the lower soil temperature and subsequent slower early growth result in reduced yields depends largely on weather conditions during the summer, particularly during the tasseling and silking stages. Slower growth may delay this process until weather conditions are better, but best yields normally occur when corn tassels and silks early.

Soil moisture. Surface mulch reduces evaporation. Wetter soil is advantageous in dry summer periods, but it is disadvantageous at planting time and during early growth, especially on soils with poor internal drainage.

Soil compaction. Interest in soil compaction has increased, probably because larger equipment is now being used and reduced tillage systems are more commonly used. Greater soil density or compaction restricts and slows root development and may cause yield declines. However, a complete understanding of the effects of soil compaction on plant growth is not available.

Wet soils compact much more easily and to a greater extent than dry soils. If at all possible, wheel traffic and tillage operations should be restricted to times when the soil is dry.

Measurements indicate increased soil compaction as tillage is reduced. The moldboard plow loosens soil uniformly to the plow's operating depth. The chisel plow and subsoilers loosen the soil where the points operate; but between points, it loosens just the upper few inches of soil. The disk loosens the soil only to the depth it operates. With no-till, of course, the soil is not loosened.

Secondary tillage implements like disk harrows and field cultivators tend to increase the soil density when used on loose, tilled soil. These tools also break up the soil aggregates, making the soil more susceptible to compaction when it is wet and then dried.

Traffic increases compaction when the soil strength

is insufficient to support the load of the tire. The pressure applied to the soil is approximately equal to the tire pressure. If the load on a tire is increased, the tire deflects to maintain a constant pressure. Compaction due to traffic is most severe when the soil is wet.

Stand establishment. Uniform planting depth, good contact between the seed and moist soil, and enough loose soil to cover the seed are necessary to produce uniform stands. Shallower than normal planting in the cool, moist soil common to many conservation tillage seedbeds may partially offset the disadvantage of lower temperatures, providing that a uniform depth is maintained and seeds are covered. Check planter adjustments frequently.

Planters must be equipped to handle the large amounts of crop residue and firm soil in no-till and some other conservation tillage seedbeds. A coulter, disk blades, or other narrow-tillage equipment can be mounted ahead of the planter unit to handle residue in the row area and to open a slot in the soil for seed placement. Extra weight on the planter may be necessary to penetrate firm, undisturbed soil.

Fertilizer placement. Phosphorus and potassium fertilizers and limestone are relatively immobile in the soil; they remain where applied unless they are incorporated by a tillage operation. Research has shown that surface-applied fertilizers (except nitrogen) remain in the upper 2 inches of soil with no-till, in the upper 3 to 4 inches with chisel-plow or disk tillage, and that they are uniformly distributed throughout the plowed layer when the tillage system includes moldboard plowing. Roots can use nutrients placed close to the surface with conservation tillage because the crop residue mulch tends to keep soil moist. Experiments in Illinois have not shown nonuniform fertilizer distribution due to conservation tillage reduces yields, so this should not be a major consideration in deciding to adopt a conservation tillage system.

Nitrogen may be applied to the soil surface or injected as anhydrous ammonia or low-pressure solutions. A coulter mounted ahead of the applicator knife may be needed if anhydrous ammonia is applied through heavy residue. Care must be taken to ensure a good seal behind the applicator; special packing wheels may be needed for the firm soil of no-till systems. Surface-applied solutions containing urea as the nitrogen carrier are subject to nitrogen loss unless they are incorporated or moved into the soil by rain. Large amounts of surface residue can interfere with soil entry and increase the potential for loss. Surface-applied ammonium nitrate has been shown to be 10 to 20 percent more efficient than urea for no-till corn in Illinois experiments.

Research indicates that 10 to 20 percent more nitrogen may be required for no-till than for conventional tillage. This need may result because the lower soil temperature reduces the rate of nitrogen release from organic matter and the wetter soils increase the potential for denitrification losses.

Weed control

Weed control is essential for profitable production with any tillage system. Cloddy soil surfaces and crop residues left by some tillage systems interfere with herbicide distribution and incorporation. Recommended herbicide rates should be used, especially with conservation tillage. (For specific herbicide recommendations, see the section entitled "1989 Weed Control for Corn, Soybeans, and Sorghum.")

Problem weeds. Perennial weeds such as milkweed and hemp dogbane may be a greater problem with conservation tillage systems. Current programs for control of weeds such as johnsongrass and yellow nutsedge call for high rates of preplant herbicides that should be thoroughly incorporated. Wild cane is also best controlled by preplant incorporated herbicides. Volunteer corn is often a problem with tillage systems that leave the corn relatively shallow. Surface-germinating weeds, such as fall panicum and crabgrass, may also increase with reduced tillage systems unless control programs are monitored closely.

Herbicide application. Surface-applied and incorporated herbicides may not give optimum performance under tillage systems that leave large amounts of crop residue and clods on the soil surface. These problems interfere with herbicide distribution and thorough herbicide incorporation.

Herbicide incorporation is impossible in no-till systems. Residual herbicides must be effective because mechanical cultivation is usually not done. Rates for residual herbicides may need to be higher with no-till and reduced tillage systems because of herbicide tie-up on crop residues and increased weed pressure. In the presence of heavy vegetation or surface residues, the performance of most herbicides may be improved by increasing the volume of spray per acre.

Cultivation. Crops can be cultivated with all tillage systems except, possibly, no-till with heavy residue.

High amounts of crop residues may interfere with some rotary hoes and sweep cultivators. Disk cultivators will work, but they may tend to bury too much residue for effective erosion control. Rolling cultivators are effective across a wide range of soil and crop residue conditions.

With the ridge-till system, special cultivation equipment is necessary to form a sufficiently high ridge and to operate through the inter-row residue. Weed control is also accomplished as ridges are rebuilt.

Herbicide carryover. The potential for herbicide carryover is greater in conservation tillage systems because higher herbicide rates may be needed and because herbicides are diluted less in the soil when moldboard plowing is not done. Herbicide carryover is affected by climatic factors and soil conditions. Breakdown is faster in warm, wet weather and soils than in cool, dry conditions. Soils with a pH above 7.4 tend to have greater problems with atrazine carryover than soils with pH values from 6.0 to 7.3.

The carryover problem can be reduced by using lower rates of the more persistent herbicides in combination with other herbicides or by using less persistent herbicides altogether. Early application of herbicides reduces the potential for carryover.

To detect harmful levels of persistent herbicide carryover, a sensitive species (bioassay) can be grown in soil samples from suspect fields. Carryover is not a problem if the same crop or a tolerant species is to be grown the next cropping season.

No-till weed control. In conventional and most conservation tillage systems, the existing weeds are destroyed before planting begins. No-till systems require a knockdown herbicide like paraquat or Roundup to control existing vegetation. The vegetation may be a grass or legume sod or early germinating annual and perennial weeds. Alfalfa, marestail, and certain perennial broadleaf weeds will not be controlled by paraquat or Roundup. It may be necessary to treat these weeds with Banvel or 2,4-D before paraquat application or after regrowth. Do not apply these translocated herbicides with paraquat because the contact action upon the foliage may prevent translocation.

Insect control

Insects should not preclude the adoption of conservation tillage systems. In corn, most soil insect problems that might be magnified by conservation tillage practices can be controlled with soil insecticides applied at planting. Outbreaks of aboveground pests that feed on foliage can be controlled with properly timed sprays. Fields with insect outbreaks should be monitored closely.

Insect populations are greatly affected by soil texture, chemical composition, moisture content, temperature, and organisms in the soils. Tillage operations affect some of these soil conditions and change the environment in which the insects must survive. Some tillage operations favor specific pests while others tend to reduce pest problems. Because insect species differ in life cycles and habits, each must be considered separately.

Northern and western corn rootworms are the primary soil insect pests of corn in Illinois. Damage is confined primarily to corn following corn. Research shows that none of the reduced tillage systems — whether no-till, chisel, or disk — increases corn rootworm damage. Although a specific tillage practice may affect corn rootworm populations in some fields in some years, none of the tillage systems seems to be an important factor in regulating corn rootworms. Moldboard plowing is not recommended as a control measure for corn rootworms.

European corn borer larvae overwinter in cornstalk residues. Tillage systems that leave cornstalks on the surface can result in increased populations of first-generation moths and subsequent damage by the first brood in late June or early July.

Black cutworm outbreaks in corn appear more frequently with conservation tillage systems than in conventionally tilled fields, probably because cutworm moths deposit eggs on vegetation or surface debris. Recent research by the Illinois Natural History Survey indicates that egg laying occurs prior to planting. Chickweed and other winter annual weeds not buried by tillage serve as hosts for egg laying and promote cutworm survival. Thus, both weediness and reduced tillage practices may contribute to problems with cutworms.

No-till pest problems

Insect problems occur more frequently in no-till corn than in other conservation tillage systems and are often more serious. No-till systems give pests a stable environment for survival and development. Soil insecticides may be profitably applied to corn following grass sod or in any rotation where grass and weeds are prevalent. It does not generally pay to apply a soil insecticide to no-till corn following corn, except in rootworm-infested areas; nor will it generally benefit soybeans or small grain following corn. A diazinon planter-box seed treatment should, however, be used to protect against damage by seed-corn beetles and seed-corn maggots.

Table 67 illustrates the effects of tillage practices on pest problems in corn, based on estimates of Extension entomologists.

Disease control. The potential for plant disease is greater when mulch is present than when fields are clear of residue. With clean tillage, residue from the previous crop is buried or otherwise removed. Because buried residue is subject to rapid decomposition, infected residue is likely to disappear though decay.

Table 67. Estimate of the Effect of Different Tillage Practices on Insect Populations in Corn[a]

Pest	Spring plowing	Fall plowing	Reduced tillage	No-till[b]	Effective chemical control[c]
Seed-corn beetles	0	0	?	+	Yes
Seed-corn maggots	0	0	?	+	Yes
Wireworm	0	—	?	+(sod)	Yes
White grubs	0	—	?	+(sod)	Yes
Corn root aphids	—	—	?	+(sod)	?
Corn rootworm	0	0	0	+(corn)	Yes
Black cutworms	?	?	?	+	Yes
Billbugs	—	—	—	+(sod)	Yes
European corn borer	—	—	+	+	Yes
True armyworms	—	—	—	+(sod)	Yes
Common stalk borer	—	—	—	+	Yes
Slugs	—	—	—	+	No

[a] + = The practice will increase the populations or potential for damage by the pest.
– = It will reduce the population or potential for damage.
0 = No effect on the pest.
? = Effect on the pest unknown.

[b] The preceding crop will have a direct influence on the pest problem(s) in no-till corn.

[c] More specific information on insect pest management is presented in the current *Insect Pest Mangement Guide — Field and Forage Crops*. This circular is revised annually; only the latest edition should be used.

Volunteer corn may be a problem unless the soil is moldboard-plowed in the fall or the zero-till system is used. If the volunteer corn is a hybrid that is susceptible to disease, early infection with diseases such as southern corn leaf blight, for instance, will increase.

Although the potential for plant disease is greater with mulch tillage than with clean tillage, disease-resistant hybrids and varieties can help reduce this problem. The erosion control benefit of reduced tillage must be balanced against the increased potential for disease. Crop rotation or modification of the tillage practice may be justified if a disease problem appears likely.

Crop yields

Conservation tillage systems have produced yields comparable to those from conventional tillage on most Illinois soils when stands are adequate and pests are controlled. Yields on poorly drained, fine-textured soils such as silty clay loam, silty clay, and clay have been consistently higher when soils are moldboard-plowed after corn. Soils with root-restricting claypan or fragipan subsoils, on the other hand, have frequently produced higher corn yields where conservation tillage is used to retain moisture (Table 68).

Drummer silty clay loam and Flanagan silt loam are poorly and somewhat poorly drained, respectively. They are moderately heavy-textured, dark-colored soils that developed under prairie vegetation. They are sticky and compact easily if tilled when wet. When corn follows soybeans, corn yields using chisel and spring disk systems are similar to yields produced by moldboard-plow tillage. Yields for continuous corn generally decrease as tillage decreases.

Blount silt loam is a somewhat poorly drained, heavy-textured, light-colored soil developed under forest vegetation. Yields for continuous corn are similar for moldboard plow and disk systems but are reduced for the no-till system.

Cisne silt loam is a very slowly permeable, poorly drained soil that is common in south central Illinois. A strongly developed argillic horizon (claypan) restricts root development and water use by the crop. Reduced evaporation with the cornstalk mulch of chisel plow, disk, and ridge-till systems conserves water for crop use, frequently producing higher yields.

Downs silt loam and Fayette silt loam are moderately well-drained and well-drained, respectively, medium-textured, light-colored soils developed under prairie-forest and forest vegetation. Yields with chisel plow and disk systems are similar to yields from the moldboard plow tillage system.

Tama silt loam is a well- to moderately well-drained, medium-textured, dark-colored soil developed under prairie vegetation. Yields for all tillage systems are quite similar when corn follows soybeans, but yields for no-till and ridge-till systems are reduced with continuous corn.

Production costs

Will the switch from a conventional moldboard plow system to a conservation tillage system be profitable? The answer depends on how one weighs the

Table 68. Corn and Soybean Yields with Moldboard Plow, Chisel Plow, Disk, No-Till, and Ridge-Till Systems

Tillage system	Flanagan silt loam and Drummer silty clay loam		Drummer silty clay loam	Flanagan silt loam and Drummer silty clay loam	Blount silt loam	Cisne silt loam		Downs-Fayette silt loam	Tama silt loam	
	corn yield, bushels per acre									
Moldboard plow[k]	..[a]	141[b]	178[c]	187[d]	118[e]	138[f]	131[g]	130[h]	182[i]	180[j]
Chisel plow	154	..	167	176	..	148	149	130	189	177
Disk	155	134	163	185	119	145	143	131	..	176
No-till	149	132	162	180	92	131	119	120	176	163
Ridge-till	..	..	..	..	..	..	144	..	187	169
	soybean yield, bushels per acre									
Moldboard plow[k]	45[l]	46[m]	53[m]	46[m]	..	34[m]	39[m]	37[m]	51[m]	..
Chisel plow	..	..	49	44	..	37	40	37	48	..
Disk	44	43	48	45	..	40	42	37	43	46[m]
No-till	41	44	48	43	..	38	41	33	45	47
Ridge-till	..	..	..	..	..	..	44	..	47	48

[a] Champaign, corn-soybean rotation, 1980-87.
[b] Champaign, continuous corn, 1980-87.
[c] Urbana, corn-soybean rotation, 1983-85.
[d] Dekalb, corn-soybean rotation, 1983-87.
[e] Elwood, continuous corn, 1978-87.
[f] Brownstown, corn-soybean rotation, 1985-87.
[g] Brownstown, corn-soybean rotation, 1985-86.
[h] Perry, corn-soybean rotation, 1980-87.
[i] Monmouth, corn-soybean rotation, 1986-87.
[j] Monmouth, continuous corn, 1984-87.
[k] Moldboard plowed in the fall, except Blount and Cisne were moldboard plowed in the spring.
[l] Row spacing was 10 inches.
[m] Row spacing was 30 inches.

Table 69. Estimated Production Costs with Different Tillage Systems

Tillage system	Cost				
	Machinery[a]	Labor[b]	Pesticide	Fertilizer	Total
	dollars per acre				
Moldboard and chisel	51.51	8.99	14-19	29-35	103.5-114.5
Chisel	48.01	7.73	14-19	29-35	98.74-109.74
Disk	43.11	7.95	14-19	29-35	94.06-105.06
No-till	31.55	4.84	15-30[c]	29-40[e]	80.39-106.39
Ridge-till	35.78	6.47	7-19[d]	29-35	78.25-96.25

[a] Machinery and labor costs calculated from Farm Machinery Selection Program, Siemens, Hamburg, and Tyrrell, 1988.
[b] Labor assumed to cost $7.50 per hour.
[c] No-till herbicide program options include early preplant, preemergent, or postemergent and knockdown.
[d] Ridge-till herbicide program options include band or broadcast applications.
[e] No-till nitrogen application options include anhydrous ammonia or UAN.

Table 70. Estimated Soil Losses with Different Tillage Systems, Crop Rotations, and Conservation Practices

Tillage systems and rotations	Soil loss[a]		
	2-percent slope, no conservation practices	5-percent slope, no conservation practices	5-percent slope, contoured
	tons per acre		
Corn-soybean rotation			
Moldboard and chisel	6.4	25.1	12.6
Chisel	4.5	17.1	8.6
Disk	3.8	14.5	7.3
No-till	0	3.4	1.7
Ridge-till	3	12.5	5.2
Combination: moldboard on flat ground, no-till on sloping land	6.4[b]	3.4[c]	1.7[c]
Corn-soybean-oats-meadow rotation			
Moldboard	2.5	9.6	4.8

[a] Soil loss calculated for Catlin and Flanagan soil series using formulas and data from *Estimating Your Soil Erosion Losses with the Universal Soil Loss Equation (USLE)*, Circular 1220, R. D. Walker and R.A. Pope, 1983.
[b] Only moldboard plow used.
[c] Only no-till used.

importance of three primary factors: yield, cost, and erosion control. The relation of yield and soil erosion to tillage system was discussed in the preceding section.

Machinery investment is one of the major production costs affected by the choice of tillage system. If new machinery must be purchased, the capital investment and the depreciation and interest costs of the equipment needed for conservation tillage will be less than for moldboard plow tillage (Table 69). Conservation tillage implements are less expensive and the necessary power units may be smaller. If conservation tillage is used on only a part of the land farmed, larger equipment will still be needed for the other portions, so there will be no savings.

With a conservation tillage system, some labor costs will be reduced because fall or spring tillage operations are reduced or eliminated. The labor saved in this way has value only if it reduces the cost of hired labor or if the saved costs of hired labor are directed into other productive activities, such as raising livestock, farming more acres, or reducing machinery costs by substituting smaller equipment.

An extra cost of additional or more expensive pesticides and fertilizers also may be associated with conservation tillage systems. For example, contact herbicides may be needed with no-till and ridge-tillage systems. These increases must be weighed against the reduced fuel and machinery repair costs necessary to perform fewer operations. Often, the reduced machinery costs associated with conservation tillage are offset by increased herbicide cost. Ridge-till can be cost effective if a contact herbicide is not required and a band application of herbicide is used. Fertilizer costs, especially nitrogen costs, can be more expensive with no-till if anhydrous ammonia is not used.

A major advantage of reduced tillage is improved erosion control (Table 70). With an appropriate soil conservation practice, such as contouring, soil losses can be reduced to the tolerance level with reduced tillage systems. If the objective is to reach that level, a conservation tillage system such as no-till will be more profitable on grain farms than an alternate method such as crop rotation of corn, soybeans, oats, and meadow.

Water Management

A superior water management program seeks to provide an optimum balance of water and air in the soil that will allow full expression of genetic potential in plants. The differences among poor, average, and record crop yields generally can be attributed to the amount and timing of soil water supply.

Improving water management is an important way to increase crop yields. By eliminating crop-water stress, you will obtain more benefits from improved cultural practices and realize the genetic potential of the cultivars now available.

To produce maximum yields, the soil must be able to provide water as it is needed by the crop. But the soil seldom has just the right amount of water for maximum crop production: A deficiency or a surplus usually exists. A good water management program seeks to avoid both extremes through a variety of measures. These measures include draining waterlogged soils; making more effective use of the water-holding capacity of soils so that crops will grow during periods of insufficient rainfall; increasing the soil's ability to absorb moisture and conduct it down through the soil profile; reducing water loss from the soil surface; and irrigating soils with low water-holding capacity.

In Illinois, the most frequent water management need is improved drainage. Initial efforts in the nineteenth century to artificially drain Illinois farmland made our soils among the most productive in the world. Excessive water in the soil limits the amount of oxygen available to plants and thus retards growth. This problem occurs where the water table is high or where water ponds on the soil surface. Removing excess water from the root zone is an important first step toward a good water management program. A drainage system should be able to remove water from the soil surface and lower the water table to about 12 inches beneath the soil surface in 24 hours and to 21 inches in 48 hours.

The benefits of drainage

A well-planned drainage system will provide a number of benefits: better soil aeration, more timely field operations, less flooding in low areas, higher soil temperatures, less surface runoff, better soil structure, better incorporation of herbicides, better root development, higher yields, and improved crop quality.

Soil aeration. Good drainage ensures that roots receive enough oxygen to develop properly. When the soil becomes waterlogged, aeration is impeded and the amount of oxygen available is decreased. Oxygen deficiency reduces root respiration and often the total volume of roots developed. It also impedes the transport of water and nutrients through the roots. The roots of most nonaquatic plants are injured by oxygen deficiency; and prolonged deficiency may result in the death of some cells, entire roots, or in extreme cases the whole plant. Proper soil aeration also will prevent rapid losses of nitrogen to the atmosphere through denitrification.

Timeliness. Because a good drainage system increases the number of days available for planting and harvesting, it can enable you to make more timely field operations. Drainage can reduce planting delays and the risk that good crops will be drowned or left standing in fields that are too wet for harvest. Good drainage may also reduce the need for additional equipment that is sometimes necessary to speed up planting when fields stay wet for long periods.

Soil temperature. Drainage can increase soil surface temperatures during the early months of the growing

season by 6° to 12°F. Warmer temperatures assist germination and increase plant growth.

Surface runoff. By enabling the soil to absorb and store rainfall more effectively, drainage reduces runoff from the soil surface and thus reduces soil erosion.

Soil structure. Good drainage is essential in maintaining the structure of the soil. Without adequate drainage the soil remains saturated, precluding the normal wetting and drying cycle and the corresponding shrinking and swelling of the soil. The structure of saturated soil will suffer further damage if tillage or harvesting operations are performed on it.

Herbicide incorporation. Good drainage can help avoid costly delays in herbicide application, particularly of postemergence herbicides. Because some herbicides must be applied during the short time that weeds are still relatively small, an adequate drainage system may be necessary for timely application. Drainage may also help relieve the cool, wet stress conditions that increase crop injury by some herbicides.

Root development. Good drainage enables plants to send roots deeper into the soil so they can extract moisture and plant nutrients from a larger volume of soil. Plants with deep roots are better able to withstand drought.

Crop yield and quality. All these benefits previously mentioned contribute to greater yields of higher-quality crops. The exact amount of the yield and quality increases depends on the type of soil, the amount of rainfall, the fertility of the soil, crop management practices, and the level of drainage before and after improvements are made. Of the few studies that have been conducted to determine the benefits of drainage, the most extensive in Illinois was initiated at the Agronomy Research Center at Brownstown. This study evaluated drainage and irrigation treatments with Cisne and Hoyleton silt loams. Yield information from 1977 through 1983 is summarized in the section entitled "Irrigation and yields."

Drainage methods

A drainage system may consist of surface drainage, subsurface drainage, or some combination of both. The kind of system you need depends in part upon the ability of the soil to transmit water. The selection of a drainage system ultimately should be based on economics. Surface drainage, for example, would be most appropriate where soils are impermeable and would therefore require too many subsurface drains to be economically feasible. Soils of this type are common in southern Illinois.

Surface drainage

A surface drainage system is most appropriate on flat land with slow infiltration and low permeability and on soils with restrictive layers close to the surface. This type of system removes excess water from the soil surface through improved natural channels, man-made ditches, and shaping of the land surface. A properly planned system eliminates ponding, prevents prolonged saturation, and accelerates the flow of water to an outlet without permitting siltation or soil erosion.

A surface drainage system consists of a farm main, field laterals, and field drains. The farm main is the outlet serving the entire farm. Where soil erosion is a problem, a surface drain or waterway covered with vegetation may serve as the farm main. Field laterals are the principal ditches that drain adjacent fields or areas on the farm. The laterals receive water from field drains, or sometimes from the surface of the field, and carry it to the farm main. Field drains are shallow, graded channels (with relatively flat side slopes) that collect water within a field.

A surface drainage system sometimes includes diversions and interceptor drains. Diversions are channels constructed across the slope of the land to intercept surface runoff and prevent it from overflowing bottomlands. Diversions are usually located at the bases of hills. These channels simplify and reduce the cost of drainage for bottomlands.

Interceptor drains collect subsurface flow before it resurfaces. These channels may also collect and remove surface water. They are used on long slopes that have grades of one percent or more and on shallow, permeable soils overlying relatively impermeable subsoils. The location and depth of these drains are determined from soil borings and the topography of the land.

The principal types of surface drainage configurations are the random and parallel systems (Figure 22). The **random system** consists of meandering field drains that connect the low spots in a field and provide an outlet for excess water. This system is adapted to slowly permeable soils with depressions too large to be eliminated by smoothing or shaping the land.

The **parallel system** is suitable for flat, poorly drained soils with many shallow depressions. In a field that is cultivated up and down a slope, parallel ditches can be arranged to break the field into shorter lengths. The excess water thus erodes less soil because it flows over a smaller part of the field before reaching a ditch. The side slopes of the parallel ditches should be flat enough to permit farm equipment to cross them. The spacing of the parallel ditches will vary according to the slope of the land.

For either the random or parallel systems to be fully effective, minor depressions and irregularities in the soil surface must be eliminated through land grading or smoothing.

Bedding is another surface drainage method that is used occasionally. The land is plowed to form a series of low, narrow ridges separated by parallel, dead furrows. The ridges are oriented in the direction of the steepest slope in the field. Bedding is adapted to the same conditions as the parallel system, but it may interfere with farm operations and does not drain the land as completely. It is not generally suited for land

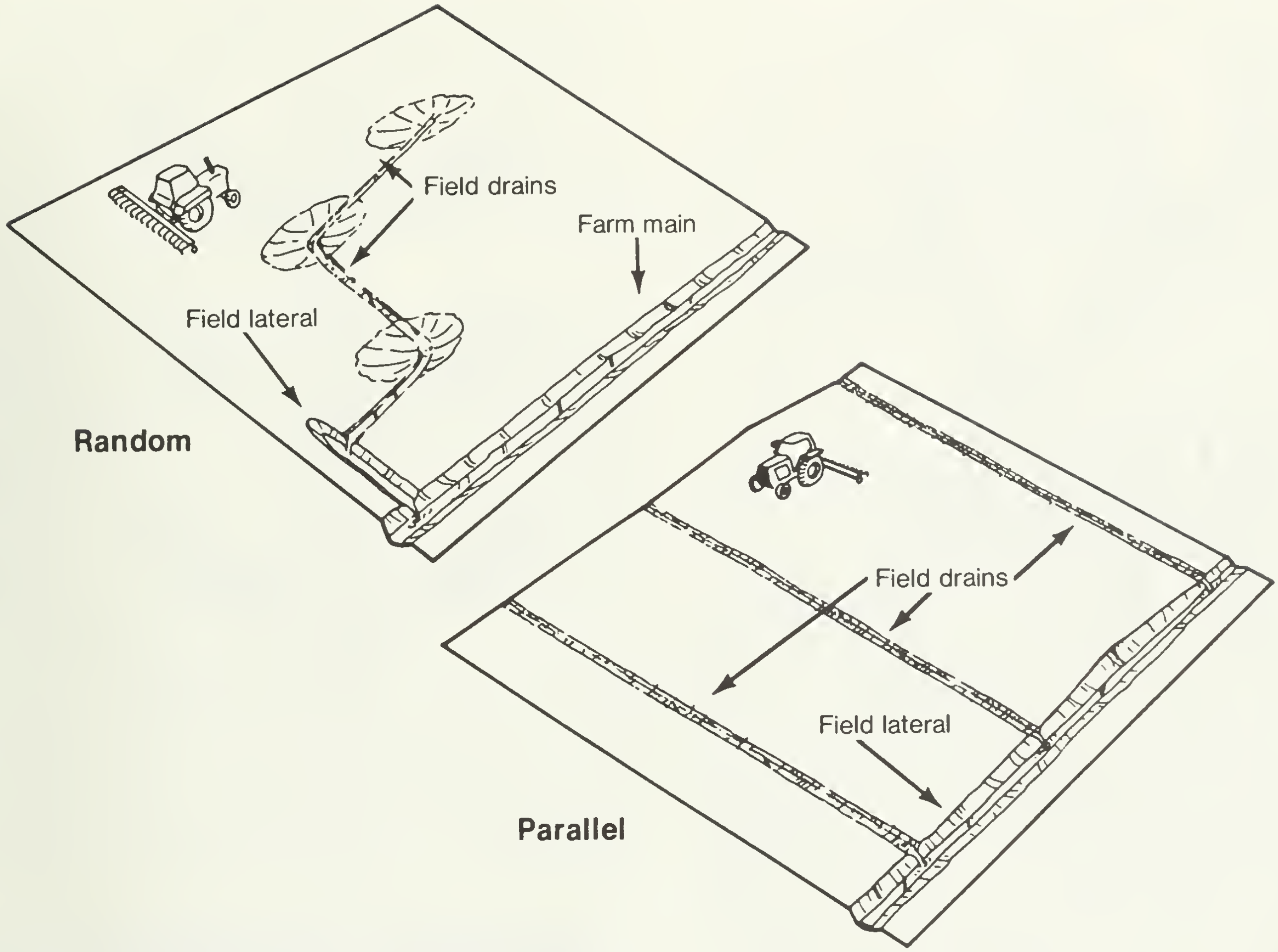


Figure 22. Types of surface drainage systems.

that is planted in row crops because the rows adjacent to the dead furrows will not drain satisfactorily. Bedding is acceptable for hay and pasture crops, although it will cause some crop loss in and adjacent to the dead furrows.

Subsurface drainage

Many of the deep, poorly drained soils of central and northern Illinois respond favorably to subsurface drainage. A subsurface drainage system is used in soils permeable enough that the drains do not have to be placed too closely together. If the spacing is too narrow, the system will not be economical. By the same token, the soil must be productive enough to justify the investment. Because a subsurface drainage system functions only as well as the outlet, a suitable one must be available or constructed. The topography of the fields also must be considered because the installation equipment has depth limitations and a minimum amount of soil cover is required over the drains.

Subsurface systems are made up of an outlet or main, sometimes a submain, and field laterals. The drains are placed underground, although the outlet is often a surface drainage ditch. Subsurface drainage conduits are constructed of clay, concrete, or plastic.

There are four types of subsurface systems: the random, the herringbone, the parallel, and the double-main (Figure 23). A single system or some combination of systems may be chosen according to the topography of the land.

For rolling land, a **random system** is recommended. With this system, the main drain is usually placed in a depression. If the wet areas are large, the submains and lateral drains for each area may be placed in a gridiron or herringbone pattern to achieve the required drainage.

With the **herringbone system**, the main or submain is often placed in a narrow depression or on the major slope of the land. The lateral drains are angled upstream on either side of the main. This system sometimes is combined with others to drain small or irregular areas. Because two laterals intersect the main at the same point, however, more drainage than necessary

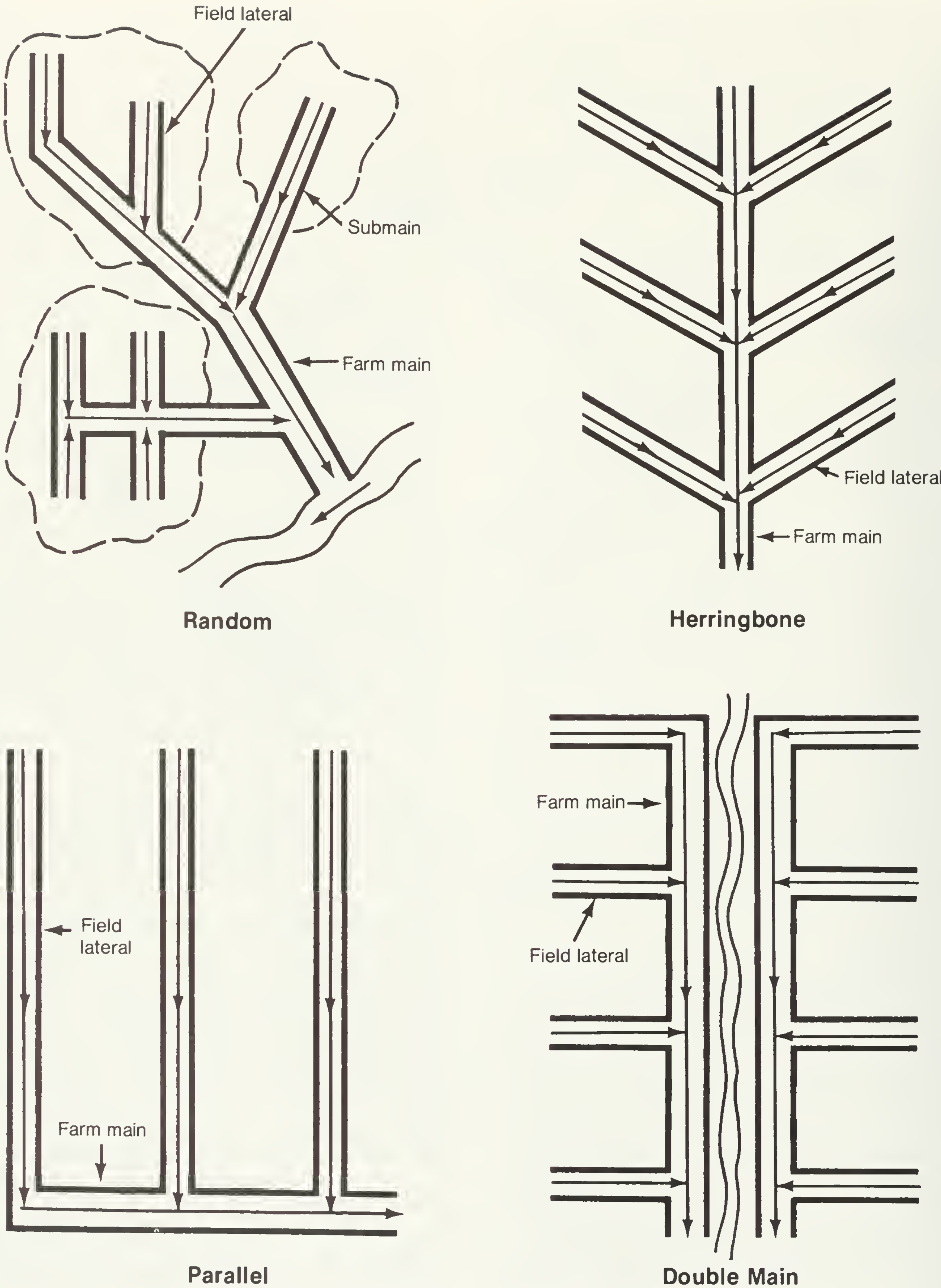


Figure 23. Types of subsurface drainage systems. The arrows indicate the direction of water flow.

may occur at that intersection point. The herringbone system may also cost more because it requires more junctions. Nevertheless, it can provide the extra drainage needed for the heavier soils that are found in narrow depressions.

The **parallel system** is similar to the herringbone system, except that the laterals enter the main from only one side. This system is used on flat, regularly shaped fields and on uniform soil. Variations are often used with other patterns.

The **double-main system** is a modification of the parallel and herringbone systems. It is used where a depression, frequently a natural watercourse, divides the field in which drains are to be installed. Sometimes the depression may be wet due to seepage from higher ground. A main placed on either side of the depression intercepts the seepage water and provides an outlet for the laterals. If only one main were placed in the center of a deep and unusually wide depression, the grade of each lateral would have to be changed at some point before it reaches the main. A double-main system avoids this situation and keeps the gradelines of the laterals uniform.

The advantage of a subsurface drainage system is that it usually drains soil to a greater depth than surface drainage. Subsurface drains placed 36 to 48 inches deep and 80 to 100 feet apart are suitable for crop production on many medium-textured soils in Illinois. When properly installed, these drains require little maintenance, and because they are underground, they do not obstruct field operations.

For more specific information about surface and subsurface drainage systems, obtain the Extension Circular 1226, *Illinois Drainage Guide*, from your county Extension adviser. This publication discusses the planning, design, installation, and maintenance of drainage systems for a wide variety of soil, topographic, and climate conditions.

The benefits of irrigation

During an average year, most regions of Illinois receive ample rainfall for growing crops; but, as shown in Figure 24, rain does not occur when the crops need it the most. From May to early September, growing crops demand more water than is provided by precipitation. For adequate plant growth to continue during this period, the required amount of water must be supplied by stored soil water or by irrigation. During the growing season, crops on deep, fine-textured soils may draw upon moisture stored in the soil, if the normal amount of rainfall is received throughout the year. But if rainfall is seriously deficient or if the soil has little capacity for holding water, crop yield may be reduced. Yield reductions are likely to be most severe on sandy soils or soils with claypans. Claypan soils restrict root growth, and both types of soils often cannot provide adequate water during the growing season.

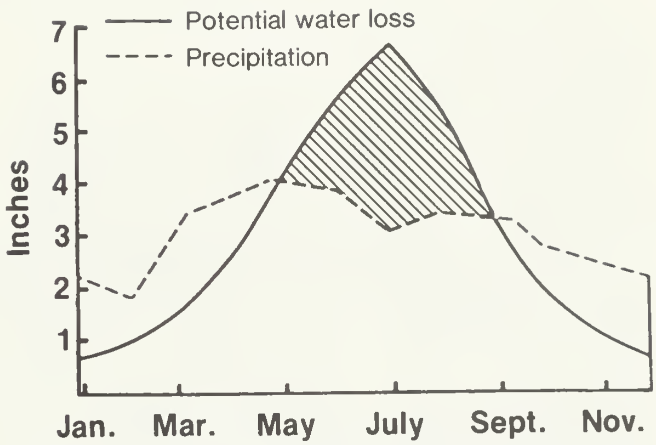


Figure 24. Average monthly precipitation and potential moisture loss from a growing crop in central Illinois.

To prevent crop-water stress during the growing season, more and more producers are using irrigation. It may be appropriate where water stress can substantially reduce crop yields and where a supply of usable water is available at reasonable cost. Irrigation is still most widely used in the arid and semi-arid parts of the United States, but it can be beneficial in more humid states such as Illinois. Almost every year, Illinois corn and soybean yields are limited by drought to some degree, even though the total annual precipitation exceeds the water lost through evaporation and transpiration (E.T.).

With current cultural practices, a good crop of corn or soybeans in Illinois needs at least 20 inches of water. All sections of the state average at least 15 inches of rain from May through August. Thus satisfactory yields require at least 5 inches of stored subsoil water in a normal year.

Crops growing on deep soil with high water-holding capacity, that is, fine-textured soil with high organic-matter content, may do quite well if precipitation is not appreciably below normal and if the soil is filled with water at the beginning of the season.

Sandy soils and soils with subsoil layers that restrict water movement and root growth cannot store as much as 5 inches of available water. Crops planted on these soils suffer from inadequate water every year. Most of the other soils in the state can hold more than 5 inches of available water in the top 5 feet. Crops on these soils may suffer from water deficiency when subsoil water is not fully recharged by about May 1 or when summer precipitation is appreciably below normal or poorly distributed throughout the season.

The probability of getting one inch or more of rain in any week is shown in Figure 25. One inch of rain per week will not replace E.T. losses during the summer, but it can keep crop-water stress from severely limiting final grain yields on soils that can hold water reasonably well. This probability is lowest in all sections of

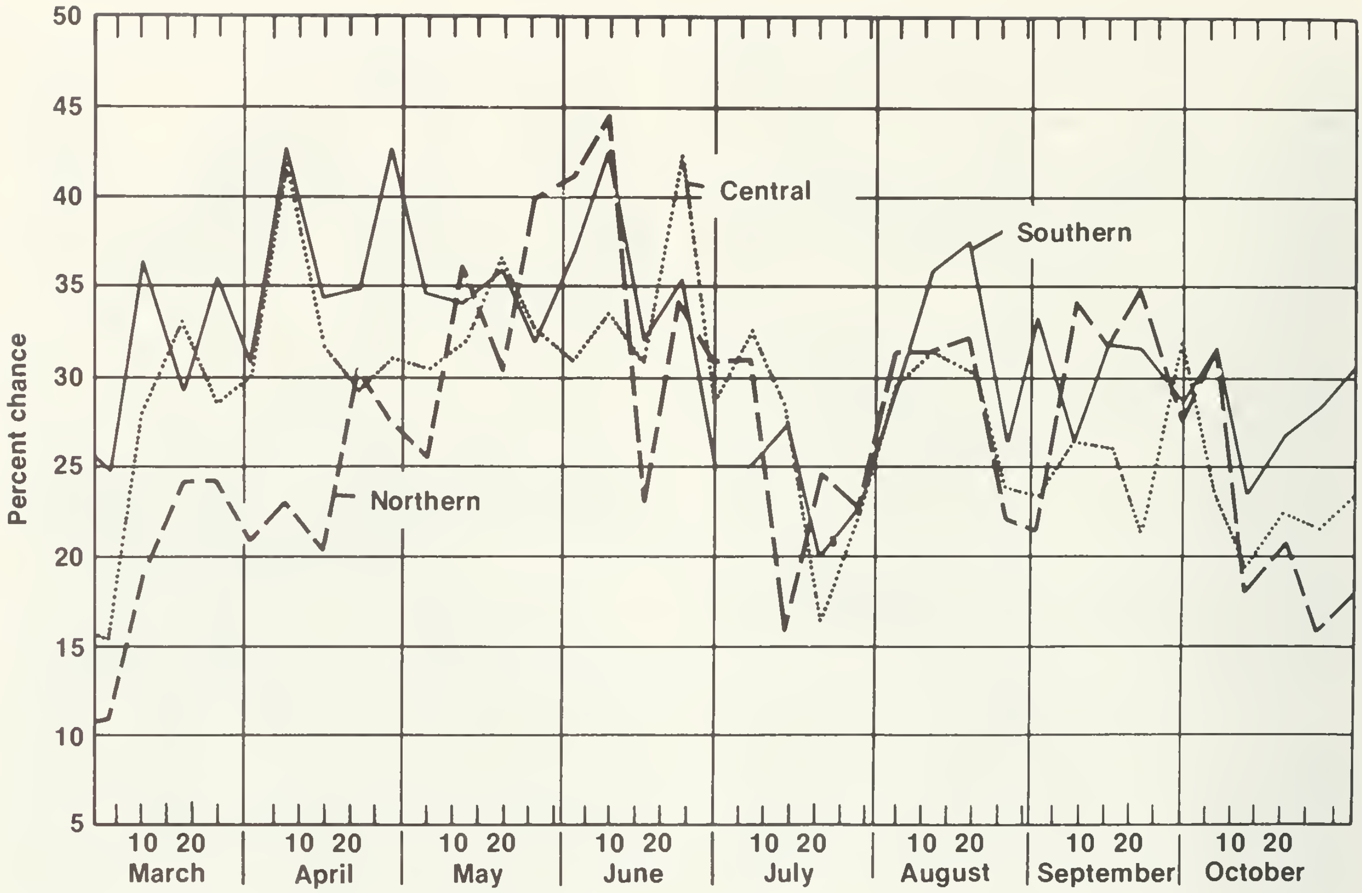


Figure 25. Chance of at least one inch of rain in one week.

Illinois during July, when corn normally is pollinating and soybeans are flowering.

Water stress delays the emergence of corn silks and shortens the period of pollen shedding, thus reducing the time of overlap between the two processes. The result is incomplete kernel formation, which can have disastrous effects on corn yields.

Corn yields may be reduced as much as 40 percent when visible wilting occurs on four consecutive days at the time of silk emergence. Studies have also shown that severe drought during the pod-filling stage causes similar yield reductions in soybeans.

Increasing numbers of farmers are installing irrigation systems to prevent the detrimental effects of water deficiency. Some years of below-normal summer rainfall and other years of erratic rainfall distribution throughout the season have contributed to the increase. As other yield-limiting factors are eliminated, adequate water becomes increasingly important to assure top yields.

Most of the development of irrigation systems has occurred on sandy soils or other soils with correspondingly low levels of available water. Some installations have been made on deeper, fine-textured soils, and other farmers are considering irrigation of such soils.

The decision to irrigate

The need for an adequate water source cannot be overemphasized when one is considering irrigation. If a producer is convinced that an irrigation system will be profitable, an adequate source of water is necessary. Such sources do not now exist in many parts of the state. Fortunately, underground water resources are generally good in the sandy areas where irrigation is most likely to be needed. A relatively shallow well in some of these areas may provide enough water to irrigate a quarter section of land. In some areas of Illinois, particularly the northern third, deeper wells may provide a relatively adequate source of irrigation water.

Many farmers pump their irrigation water from streams, which can be a relatively good and economical source, providing the stream does not dry up in a droughty year. Impounding surface water on an individual farm is possible in many areas of the state, and some farmers are doing that. However, an appreciable loss may occur both from evaporation and from seepage into the substrata. Generally, 2 acre-inches of water should be stored for each acre-inch actually applied to the land. Although the water development costs in many areas may be beyond the range of

feasibility for individual farmers, developments by groups of farmers, cooperatives, or governmental agencies could produce a sufficient water supply in one containment for a number of irrigators.

To make a one-inch application on one acre (one acre-inch), 27,000 gallons of water are required. A flow of 450 gallons per minute will give one acre-inch per hour. Thus a 130-acre, center-pivot system with a flow of 900 gallons per minute can apply one inch of water over the entire field in 65 hours of operation. Because some of the water is lost to evaporation and some may be lost from deep percolation or runoff, the net amount added will be less than one inch.

The Illinois State Water Survey and the Illinois State Geological Survey at Urbana can provide information about the availability of irrigation water. Submit a legal description of the site planned for development of a well and request information regarding its suitability for irrigation well development. Once you decide to drill a well, the Water Use Act of 1983 requires you to notify the local Soil and Water Conservation District office if the well is planned for an expected or potential withdrawal rate of 100,000 gallons or more per day. There are no permit requirements or regulatory provisions.

An amendment passed in 1987 allows Soil and Water Conservation districts to limit the withdrawals from large wells if domestic wells meeting state standards are affected by localized drawdown. The legislation affects Kankakee, Iroquois, Tazewell, and McLean counties.

The Riparian Doctrine, which governs the use of surface waters, states that one is entitled to a reasonable use of the water that flows over or adjacent to his or her land as long as one does not interfere with someone else's right to use the water. No problem results as long as water is available for everybody. But when the amount of water becomes limited, legal determinations become necessary as to whether one's water use interferes with someone else's rights. It may be important to establish a legal record to verify the date on which the irrigation water use began.

Assuming that it will be profitable to irrigate and that an assured supply of water is available, how do you find out what type of equipment is available and what is best for your situation? University representatives have discussed this question in various meetings around the state, although they cannot design a system for each individual farm. Your county Extension adviser can provide lists of dealers located in and serving Illinois. This list includes the kinds of equipment each dealer sells, but it will not supply information about the characteristics of those systems.

We suggest that you contact as many dealers as you wish to discuss your individual needs in relation to the type of equipment they sell. You will then be in a much better position to determine what equipment to purchase.

Subsurface irrigation

Subirrigation can offer the advantages of good drainage and irrigation using the same system. During wet periods, the system provides drainage to remove excess water. For irrigation, water flows back into the drains and then into the soil.

This method is most suitable for land areas where the slope is less than 2 percent, with either a relatively high water table or an impermeable layer at 3 to 10 feet below the surface. The impermeable layer ensures that applied water will remain where needed and that a minimum quantity of water will be sufficient to raise the water table.

The free water table should be maintained at 20 to 30 inches below the surface. This level is controlled and maintained at the head control stands, and water is pumped accordingly. In the event of a heavy rainfall, pumps must be turned off quickly and the drains opened. As a general rule, to irrigate during the growing season, you must deliver a minimum of 5 gallons per minute per acre.

The soil should be permeable enough to allow rapid water movement, so that plants are well supplied in peak consumption periods. Tile spacing is a major factor in the cost of the total system and perhaps the most important single variable in its design and effectiveness. Where subirrigation is suitable, the optimum system will have closer drain spacings than a traditional drainage system.

Irrigation and yields

In 1974, irrigation research on corn and soybeans was initiated on Plainfield sand at the Illinois River Valley Sand Field in Mason County. From 1974 to 1976, three irrigation frequencies were studied: daily, twice a week, and once a week. Total amount of water per week was constant and equivalent to about one-fourth inch per day. Corn yields of 180 bushels per acre and soybean yields of 58 bushels per acre were obtained in 1974. Nonirrigated yields were not taken.

In the following years, 1975 and 1976, corn yields of slightly more than 200 bushels per acre were obtained with irrigation and high fertility treatments. Nonirrigated corn yielded 70 to 80 bushels per acre with the same fertility treatments. Irrigated corn with no added fertilizer yielded less than 30 bushels per acre on this sandy soil. Full-season soybeans yielded 55 and 45 bushels per acre, respectively, in 1975 and 1976. The yields from nonirrigated soybean plots in those years were 30 and 16 bushels, respectively.

Yield comparisons have been made since 1979 for corn hybrids and soybean varieties under irrigation. Yields as high as 180 bushels for corn and 64 bushels for soybeans have been obtained during the period 1979 through 1983.

An experiment on the Sand Field from 1974 through 1978 tested the effects of fertilization on irrigated corn plots. Some plots received no fertilizer, some received a 120-60-60 fertilizer, some a 300-150-150 fertilizer, some sludge, and some manure (Table 71). Enough sludge was applied to supply approximately 300 pounds of nitrogen per acre per year. The sludge also supplied adequate phosphorus, although potash supplements were necessary. The manure supplied about 200 pounds of nitrogen per acre per year. In 1979 the same plots were planted with soybeans without any additional treatment; Table 71 shows yields for both crops. The significantly lower figures for the plots without fertilizer treatment indicate that adequate fertilization and irrigation are both essential to high-yield production.

In 1977 an experiment was initiated at the Agronomy Research Center at Brownstown to evaluate irrigation and drainage variables on Cisne and Hoyleton silt loams. Surface drainage was accomplished by land shaping to assure uniform, slow runoff. Subsurface drainage utilized perforated plastic drain tubes, 3 inches in diameter, installed on 20-foot spacings. The tubes were placed at a shallow depth, just above the claypan layer. Surface irrigation water was distributed through gated pipe and ran down furrows between the rows. Sprinkler irrigation with a solid-set system used a low application rate. A pond constructed on the farm was the water source, and the plots were in the pond's watershed. Runoff water, whether from rain or from irrigation, accumulated in the pond.

Drainage had little effect on corn yields in 1978, whereas irrigation increased yields from 53 bushels per acre to 150 bushels per acre. In 1979, however, drainage treatments were more influential on corn yields than was irrigation. In this year, water standing for a number of days on the surface of undrained plots reduced yields to only 23 bushels per acre. Plots with subsurface drainage, on the other hand, yielded 160 bushels per acre without irrigation and 195 bushels per acre with irrigation.

Corn plots that had been neither drained nor irrigated yielded an average of 81 bushels per acre, and those with good drainage and irrigation yielded an average of 161 bushels per acre for the 7 years 1977 through 1983. The average yield attributed to drainage alone was 18 bushels per acre, and that attributable to irrigation alone was 41 bushels per acre over the 7 years. Little difference in corn yield was found between plots that had received sprinkler irrigation and those that had received surface irrigation. Subsurface drainage alone gave higher corn yields than surface drainage alone, 99 bushels per acre as compared with 79. The combination of surface plus subsurface drainage produced 92 bushels per acre. Of the irrigated plots, those with drainage treatments averaged about 40 bushels per acre more than those without drainage treatments. Of the drained plots, those with irrigation treatments averaged about 70 bushels per acre more than those without irrigation treatments.

Table 71. Corn and Soybean Yields on Fertilized and Unfertilized Irrigated Sand Field Plots

Treatment given, 1974-1978	Corn yield, 1974-1978	Soybean yield, 1979[a]
	bushels per acre	
No fertilizer	32	58
120-60-60 fertilizer	120	68
300-150-150 fertilizer	184	67
Sludge and potash	179	75
Manure	139	63

[a] No fertilizer given this year.

Soybean drainage and irrigation treatments were initiated in 1980. To date, soybeans on both irrigated and drained plots have shown a yield increase of 10 bushels per acre compared with soybeans grown with neither treatment. Irrigation or drainage alone produced no yield advantage.

An irrigation experiment was begun in 1979 at Norris Mine in Fulton County as part of a comprehensive research program for reclaiming strip-mined land. Corn grown on nonirrigated mine spoil has yielded an average of 92 bushels per acre over the 5 years 1979 to 1983. Irrigation increased yields by an average of 48 bushels per acre per year. Corn grown on nonirrigated mine spoil with 18 inches of added topsoil averaged 103 bushels per acre over the 5 years, and irrigation produced an average increase of 78 bushels per acre per year. Soybeans grown on mine spoil with added topsoil averaged 37 bushels per acre without irrigation and only 48 bushels per acre with irrigation from 1980 to 1983.

Irrigation for double-cropping

Proper irrigation can eliminate the most serious problem in double-cropping: inadequate water to get the second crop off to a good start. No part of Illinois has better than a 30-percent chance of getting an inch or more of rain during any week in July and most weeks in August. With irrigation equipment available, double-crop irrigation should be a high priority. If one is considering irrigating, the possibility of double-cropping should be taken into account in making the decision about irrigation. Soybeans planted at Urbana on July 6 following a wheat harvest have yielded as much as 38 bushels per acre with irrigation. In Mason County, soybeans planted the first week in July have yielded as much as 30 bushels per acre with irrigation.

While it may be difficult to justify investing in an irrigation system for double-cropping soybeans alone, the potential benefits from irrigating other crops may make the investment worthwhile. Some farmers report that double-cropping is a top priority in their irrigation programs.

Fertigation

The method of irrigation most common in Illinois, the overhead sprinkler, is the one best adapted to

applying fertilizer along with water. Fertigation permits nutrients to be applied to the crop as they are needed. Several applications can be made during the growing season with little if any additional application cost. Nitrogen can be applied in periods when the crop has a heavy demand for both nitrogen and water. Corn uses nitrogen and water most rapidly during the 3 weeks before tasseling. About 60 percent of the nitrogen needs of corn must be met by silking time. Generally, nearly all the nitrogen for the crop should be applied by the time it is pollinating, even though some uptake occurs after this time. Fertilization through irrigation can be a convenient and timely method of supplying part of the plant's nutrient needs.

In Illinois, fertigation appears to be best adapted to sandy areas where irrigation is likely to be needed even in the wettest years. On finer-textured soils with high water-holding capacity, nitrogen might be needed even though water is adequate. Neither irrigating just to supply nitrogen nor allowing the crop to suffer for lack of nitrogen is an attractive alternative. Even on sandy soils, only part of the nitrogen should be applied with irrigation water; preplant and sidedress applications should provide the rest of it.

Other problems associated with fertigation can only be mentioned here. These include (1) possible lack of uniformity in application, (2) loss of ammonium nitrogen by volatilization in sprinkling, (3) loss of nitrogen and resultant ground-water contamination by leaching if overirrigation occurs, (4) corrosion of equipment, and (5) incompatibility and low solubility of some fertilizer materials. Discussions of these factors can be found in the *Illinois Irrigation Newsletter*.

Cost and return

The annual cost of irrigating field corn with a center-pivot system in Mason County was estimated in 1987 to vary from $95 to $140 per acre. The lower figure is for a leased low-pressure system with a 50-horsepower electric motor driving the pump. The higher figure is for a purchased high-pressure system with a 130-horsepower diesel engine. Additional costs associated with obtaining a yield large enough to offset the cost of irrigation were estimated to be about $30 per acre per year, for a total irrigation cost of $125 to $170 per acre per year. The total investment for the purchased high-pressure irrigation system, including pivot, pump and gear head, diesel engine, and a 100-foot well, amounted to $450 per acre. If the low-pressure system were purchased, the total investment for the system, including pivot, pump, electric motor, and a 100-foot well, would be $400.

Irrigation purchases should be based on sound economics. The natural soil-water storage capacity for some soils in Illinois is too good to warrant supplemental irrigation. Based on the assumed fixed and variable costs of about $110 per acre per year, it would require an annual yield differential of about 50 bushels of corn ($2.20 a bushel) or 18 bushels of soybeans ($6.00 a bushel) to break even. For irrigation to pay off, these yield differentials would have to be met on the average, over the 10- to 15-year life of the irrigation system. Some of the deep, fine-textured soils in Illinois simply would not regularly support these yield increases.

Irrigation scheduling

Experienced irrigators have developed their own procedures for scheduling applications, whereas beginners may have to determine timing and rates of application before they feel prepared to do so. Irrigators generally follow one of two basic scheduling methods, each of which has many variations.

The first method involves measuring soil water and plant stress by (1) taking soil samples at various depths with a soil probe, auger, or shovel and then measuring or estimating the amount of water available to the plant roots; or (2) inserting instruments such as tensiometers or electrical resistance blocks into the soil to desired depths and then taking readings at intervals; or (3) measuring or observing some plant characteristics and then relating them to water stress.

Although in theory the crop can utilize 100 percent of the water that is available, the last portion of that water is not actually as available as the first water that the crop takes from the soil. Much like a half-wrung-out sponge, the remaining water in the soil following 50-percent depletion is more difficult to remove than the first half of the plant-available water.

The 50-percent depletion figure is often used to schedule irrigation. For example, if a soil holds 3 inches of plant-available water in the root zone, then we could allow 1½ inches to be used by the crop before replenishing the soil water with irrigation.

Soil samples

Estimating when the 1½ inches is used, or when 50-percent depletion occurs, can be done by a number of methods. One of the simplest is to estimate the amount of depletion by the "feel" method, which involves taking a sample from various depths in the active root zone with a spade, soil auger, or soil probe. It is important to dig a shallow hole to see how the soil looks at 6 to 12 inches early in the irrigation season. As the rooting depth extends to 3 feet, it may be wise to inspect a soil sample from the 9- to 18-inch level and another from the 24- to 30-inch level. Observing only the surface can be misleading on sandy soils because the top portion dries fairly quickly in the summer. To use this method of sampling, follow the guidelines shown in Table 72 to identify the depletion range you are in.

Tensiometers

Tensiometers are most suitable for sandy or loamy soils because the changes in soil-water content can be

Table 72. Behavior of Soil at Selected Soil-Water Depletion Amounts

Available water remaining in the soil	Soil type	
	Sands	Loamy sand/sandy loam
Saturated, wetter than field capacity	Free water appears when soil ball is squeezed	Free water appears when soil ball is squeezed
100% available (field capacity)	When soil ball is squeezed, wet outline on hand, but no free water	When soil ball is squeezed, wet outline on hand, but no free water
75 to 100%	Sticks together slightly	Forms a ball that breaks easily
50 to 75%	Appears dry; will not form a ball	Appears dry; will not form a ball
Less than 50%	Flows freely as single grains	Flows freely as grains with some small aggregates

adequately described by the range of soil moisture tension (SMT) in which they operate. As plant roots dry the soil, SMT increases and water is pulled from the tensiometer into the surrounding soil, thereby increasing the reading on the vacuum gauge. After irrigation or rainfall, water replenishes the dry soil and SMT decreases. The vacuum developed in the tensiometer pulls water back through the porous ceramic tip, and the dial gauge reading decreases. By responding to both wetting and drying, a tensiometer can yield information on the effect of crop transpiration or water additions to soil-water status.

A tensiometer must be installed carefully to ensure meaningful readings. Improper use may be worse than not using a tensiometer — because false readings can result in poorly timed irrigation. Before use, each tensiometer assembly must be soaked in water overnight; then the bubbles and dissolved gases must be removed from the water within the tube and ceramic cup. This procedure can be done by using boiled water and a small suction pump that is available from tensiometer manufacturers.

The tensiometer should be installed by creating a hole with a soil probe to within 3 to 4 inches of the desired depth, then pounding a rod with a rounded end to the final depth. The rod tip should be shaped like the tensiometer tip to ensure a good, porous cup-to-soil contact. Placement of tensiometers should be made according to two principles: (1) the tensiometer should be readily accessible if it is to be used; and (2) field placement of tensiometers should be made to stagger the readings throughout the irrigation cycle.

Tensiometers are available in lengths ranging from 6 inches to 4 feet. The length required depends on the crop grown, with lengths chosen to gain accurate information in the active root zone. For shallow-rooted vegetable crops, a single tensiometer per station, at a 6- to 9-inch depth, may be sufficient. Multiple-depth stations for corn or soybeans will allow you to track the depletion and recharge of soil water at several depths throughout the season. Because the active root zone shifts as the plant matures, water extraction patterns change as well. If you want to go with a single depth station, refer to Table 73 for the proper depths of placement.

Tensiometers may require servicing if SMT increases

Table 73. Tensiometer Placement Depth for Selected Crops

	Depth, inches	Depth, centimeters
Soybeans	18	46
Corn	12	30
Snap beans	9	23
Cucumbers	9	23

to more than 80 centibars. At this tension, air enters the porous cup and the vacuum is broken. Tensiometers that have failed in this manner can be put back into service by filling them with deaerated water. Servicing can be done without removing the tensiometer from the soil. If proper irrigation levels are maintained, the SMT should not rise to levels sufficient to break the vacuum.

Moisture blocks

Moisture blocks (sometimes referred to as electrical resistance blocks or gypsum blocks) are small blocks of gypsum with two embedded electrodes. The block operates on the principle that the electrical resistance of the gypsum is affected by water content.

When saturated, the gypsum block has low electrical resistance. As it dries, the electrical resistance increases. The moisture blocks are placed in the soil and electrical leads coming from the embedded electrodes are allowed to protrude from the soil surface. These leads are connected to a portable instrument that includes an electrical resistance meter and a voltage source.

When a reading is desired, a voltage is applied and the resulting reading is recorded. The reading is converted to a soil-water content by using a predetermined calibration curve relating resistance to water content. Soil moisture blocks work well in fine- and medium-textured soils and are not recommended for sandy soils. The increase in fine-textured soil irrigation in Illinois, particularly for seed corn, may prompt an increase in the use of moisture blocks. As with tensiometers, a good soil contact is absolutely necessary for meaningful readings. Soil water must be able to move in and out of the blocks as if the blocks were part of the soil. Any gap between the block and the surrounding soil will prevent this movement.

Another method of scheduling, frequently called the "checkbook method," involves keeping a balance of the amount of soil water by measuring the amount of rainfall and then measuring or estimating the amount of water lost from crop use and evaporation. When the water drops to a certain level, the field is irrigated. Computer techniques are also available for estimating water loss, computing the water balance, and predicting when irrigation is necessary.

Management requirements

Irrigation will provide maximum benefit only when it is integrated into a high-level management program. Good seed or plant starts of proper genetic origin planted at the proper time and at an appropriate population, accompanied by optimum fertilization, good pest control, and other recommended cultural practices are necessary to assure the highest benefit from irrigation.

Farmers who invest in irrigation may be disappointed if they do not manage to irrigate properly. Systems are so often overextended that they cannot maintain adequate soil moisture when the crop requires it. For example, a system may be designed to apply 2 inches of water to 100 acres once a week. In two or more successive weeks, soil moisture may be limiting, with potential evapotranspiration equaling 2 inches per week. If the system is used on one 100-acre field one week and another field the next week, neither field may receive much benefit, especially if water stress comes at a critical time, such as during pollination of corn or soybean seed development. Inadequate production of marketable products may result.

Currently we suggest that irrigators follow the cultural practices they would use for the most profitable yield in a year of ideal rainfall. In many parts of the state, 1975, 1981, and 1982 were such years. If a farmer's yield is not already appreciably above the county average for that particular soil type, he or she needs to improve management of other cultural factors before investing in an irrigation system.

The availability of irrigation on the farm permits the use of optimum production practices every year. If rains come as needed, the investment in irrigation equipment will have been unnecessary that year, but no operating costs will be involved. When rainfall is inadequate, however, the yield potential can still be realized with irrigation.

Illinois Irrigation Newsletter

The University of Illinois College of Agriculture issues the *Illinois Irrigation Newsletter*, which covers items of particular concern to irrigators. A modest subscription charge covers the cost of printing and mailing. Subscription forms may be obtained from county Extension offices or by writing to the Agricultural Newsletter Service, Cooperative Extension Service, 116N Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois 61801.

1989 Weed Control for Corn, Soybeans, and Sorghum

This guide is based on the results of research conducted by the University of Illinois Agricultural Experiment Station, other experiment stations, and the United States Department of Agriculture (USDA). Consideration has been given to the soils, crops, and weed problems of Illinois.

The effectiveness of herbicides is influenced by rainfall, soil factors, weed spectrum, method of application, and formulation. Under certain conditions, some herbicides may damage the crop to which they are applied. In some cases, herbicide residues in the soil may damage crops that are grown later; and some herbicides may move outside the target area, affecting desirable plants.

Precautions

When selecting a herbicide, consider both the risk involved in using the herbicide and the yield losses caused by weeds. You can reduce risks by taking the following precautions:

- Apply herbicides only to those crops for which use has been approved.
- Clean tanks thoroughly when changing herbicides, especially when using a postemergence herbicide. Use a 1-percent ammonia wash to clean any traces of 2,4-D or dicamba from the tank before spraying soybeans. Some herbicide labels provide cleaning suggestions.
- Correctly calibrate the sprayer, and check the nozzle output and adjustment before adding the herbicide.
- Use recommended rates. Applying too much herbicide is costly and, in addition, can damage crops and cause illegal residues. Using too little herbicide can result in poor weed control.
- Apply herbicides only at times specified on the label. Observe the recommended intervals between treatment and pasturing or between treatment and harvesting of crops, as well as recommended intervals between application and subsequent planting of crops.
- Guard against drift injury to nearby susceptible plants, such as ornamentals and vegetables, as well as agronomic crops. Mist or vapors from 2,4-D and dicamba sprays may drift several hundred yards. Whenever possible, operate sprayers at low pressure with tips that deliver large droplets. Spray only on calm days or make sure that the wind is not moving toward susceptible crop plants and ornamentals. Use special precaution with Command.
- Applicators should use appropriate precautions to protect themselves and others from exposure to herbicides.
- Be sure that animals or persons not directly involved in the operation are not present in the area. Use special precautions near residential areas.
- Several herbicide labels carry the following groundwater warnings under either the environmental hazard or the groundwater advisory section. "X is a chemical that can travel (seep or leach) through soil and enter groundwater which may be used as drinking water. X has been found in groundwater as a result of its use as a herbicide. Users of this product are advised not to apply X where the soils are very permeable (that is, well-drained soils such as loamy sands) and the water table is close to the surface."
- Check the herbicide label for the proper method of container disposal. Triple rinse, puncture, and haul metal containers to an approved sanitary landfill. Haul paper containers to a sanitary landfill, or burn them in an approved manner.
- Promptly return unused herbicides to a safe storage place. Store them in the original containers away from unauthorized persons, particularly children.
- Because formulations and labels are sometimes

changed and government regulations modified, always refer to the most recent product label.

This guide has been developed to help you use herbicides as effectively and safely as possible. Because no guide can remove all the risk involved, however, the University of Illinois and its employees assume no responsibility for the results of using herbicides, even if they have been used according to the suggestions, recommendations, or directions of the manufacturer or any governmental agency.

Cultural and mechanical control

Good cultural practices that aid in weed control include adequate seedbed preparation, adequate fertilization, crop rotation, planting on the proper date, use of the optimum row width, and seeding at the rate required for optimum stands.

Planting in relatively warm soil can help the crop emerge quickly and compete better with weeds. Good weed control during the first 3 to 5 weeks is extremely important for both corn and soybeans. If weed control is adequate during that period, corn and soybeans will usually compete quite well with most of the weeds that begin growing later.

Narrow rows will shade the centers faster and help the crop compete better with the weeds. If herbicides alone cannot give adequate weed control, however, then keep rows wide enough to allow for cultivation. Some of the newer herbicides are improving the chances of achieving adequate control without cultivation.

If a preemergence or preplant herbicide does not appear to be controlling weeds adequately, use the rotary hoe while weeds are still small enough to be controlled. Use the rotary hoe after weed seeds have germinated but before most weeds have emerged. Operate it at 8 to 12 miles per hour, and weight it enough to stir the soil and kill the tiny weeds. Rotary hoeing also aids crop emergence if the soil is crusted.

Row cultivators also should be used while weeds are small. Throwing soil into the row can help smother small weeds. Cultivate shallowly to prevent injury to crop roots.

Herbicides can provide a convenient and economical means of early weed control and allow for delayed and faster cultivation. Furthermore, unless the soil is crusted, it may not be necessary to cultivate some fields if herbicides are controlling weeds adequately.

Herbicide incorporation

Soil-applied herbicides are incorporated to minimize surface loss, reduce dependence upon rainfall, and provide appropriate placement of the herbicide. Herbicides such as Sutan+ and Eradicane are incorporated soon after application to minimize surface loss from volatilization. Treflan and Sonalan are incorporated to minimize loss due to photodecomposition and volatilization. Triazine herbicides such as atrazine and Bladex and acetamide herbicides such as Lasso and Dual may be incorporated to minimize dependence upon timely rainfall; but because these herbicides are not lost as quickly from the soil surface, the timing of incorporation is less critical.

Incorporation should place the herbicide uniformly throughout the top 1 or 2 inches of soil for the best control of small-seeded annual weeds that germinate at shallow depths. Slightly deeper placement may improve the control of certain weeds from deep-germinating seed under relatively dry conditions. Incorporating too deeply, however, tends to dilute the herbicide and may reduce the effectiveness. The field cultivator and tandem disk place most of the herbicide at about one-half the depth of operation. Thus for most herbicides, the suggested depth of operation is 3 to 4 inches.

Thorough incorporation with ground-driven implements requires two passes. Single-pass incorporation can result in streaked weed control, especially in moist soils. It can also cause concentrated zones of herbicide, which are conducive to crop injury. Single-pass incorporation may be adequate with some herbicides that tend to move laterally in the soil. It may also be adequate with some equipment, especially if rotary hoeing, cultivation, or subsequent herbicide treatments are used to improve weed control. If the first pass sufficiently covers the herbicide to prevent surface loss, the second pass can be delayed until immediately before planting.

The depth and thoroughness of incorporation depend upon the type of equipment used, the depth and speed of operation, the texture of the soil, and the amount of soil moisture. Field cultivators and tandem disks are commonly used for incorporation; however, disk-chisels and other combination tools are being used in some areas.

Field cultivators

Field cultivators are frequently used for herbicide incorporation. They should have three or more rows of shanks with an effective shank spacing of no more than 8 to 9 inches (a spacing of 24 to 27 inches on each of three rows). The shanks may be equipped with points or sweeps. Sweeps usually give better incorporation, especially when soil conditions are a little too wet or dry for optimum soil flow and mixing. Sweeps for C-shank cultivators should be at least as wide as the effective shank spacing.

The recommended operating depth for the field cultivator is 3 to 4 inches. It is usually sufficient to operate the field cultivator only deep enough to remove tractor tire depressions. The ground speed should be at least 6 miles per hour. The field cultivator must be operated in a level position so that the back shanks are not operating in untreated soil, which would result in streaked weed control. Two passes are recommended to obtain uniform weed control. If single-pass incorporation is preferred, the use of wider sweeps or

narrower spacing with a 3- to 5-bar harrow or rolling baskets pulled behind will increase the probability of obtaining adequate weed control.

Tandem disks

Tandem disk harrows invert the soil and usually place the herbicide deeper in the soil than most other incorporation tools. Tandem disks used for herbicide incorporation should have disk blade diameters of 20 inches or less and blade spacings of 7 to 9 inches. Larger disks are considered primary tillage tools and should not be used for incorporating herbicides. Spherical disk blades give better herbicide mixing than do conical disk blades.

Tandem disks usually place most of the herbicide in the top 50 to 60 percent of the operating depth. For most herbicides, the suggested operating depth is from 3 to 4 inches. Two passes are recommended to obtain uniform mixing with a double disk. A leveling device (harrow or rolling baskets) should be used behind the disk to obtain proper mixing. Recommended ground speeds are usually between 4 and 6 miles per hour. The speed should be sufficient to move the soil the full width of the blade spacing. Lower speeds can result in herbicide streaking.

Combination tools

Several new tillage tools combine disk gangs, field cultivator shanks, and leveling devices. Many of these combination tools can handle large amounts of surface residue without clogging and yet leave considerable crop residue on the soil surface for erosion control. Results indicate that these combination tools may provide more uniform one-pass incorporation than does a disk or field cultivator, but one pass with them is generally no better than two passes with the disk or field cultivator.

Chemical weed control

Plan your weed-control program to fit your soils, tillage program, crops, weed problems, and farming operations. Good herbicide performance depends on the weather and on wise selection and application. Your decisions about herbicide use should be based on the nature and seriousness of your weed problems. The herbicide selectivity tables at the end of this guide indicate the susceptibility of our most common weed species to herbicides.

Corn or soybeans may occasionally be injured by some of the herbicides registered for use on those crops. To reduce injury to crops, apply the herbicide uniformly, at the time specified on the label, and at the correct rate. (See the section entitled "Herbicide rates.") Crop tolerance ratings for various herbicides are also given in the tables at the end of this guide. Unfavorable conditions such as cool, wet weather, delayed crop emergence, deep planting, seedling diseases, soil in poor physical condition, and poor-quality seed may contribute to crop stress and herbicide injury. Hybrids and varieties also vary in their tolerance to herbicides and environmental stress factors. Once injured by a herbicide, plants are prone to disease.

Crop planting intentions for next season must also be considered. Where atrazine or simazine are used, you should not plant spring-seeded small grains, small-seeded legumes and grasses, or vegetables the following year. Be sure that the application of Treflan or similar herbicides for soybeans is uniform and sufficiently early to reduce the risk of injury to wheat or corn following soybeans. Note that certain cropping restrictions apply for Command, Scepter, Classic, Preview, and Lorox Plus. Refer to the herbicide label for information about cropping sequence and appropriate intervals to allow between different crops.

Names of some herbicides

Trade	Common (generic)
AAtrex, Atrazine	atrazine
Ala-Scept	alachlor plus imazaquin
Amiben	chloramben
Assure	quizalofop
Banvel	dicamba
Basagran	bentazon
Bicep	metolachlor plus atrazine
Bladex	cyanazine
Blazer, Tackle	acifluorfen
Bronco	alachlor plus glyphosate
Buctril	bromoxynil
Buctril/atrazine	bromoxynil plus atrazine
Bullet	alachlor plus atrazine
Butyrac 200, Butoxone	2,4-DB
Cannon	alachlor plus trifluralin
Classic	chlorimuron
Cobra	lactofen
Command	clomazone
Commence	clomazone plus trifluralin
Dual	metolachlor
Eradicane	EPTC plus safener
Eradicane Extra	EPTC plus safener and extender
Evik	ametryn
Extrazine II	cyanazine plus atrazine
Fusilade 2000	fluazifop-P
Gramoxone Super	paraquat
Laddok	bentazon plus atrazine
Lariat	alachlor plus atrazine
Lasso, several others	alachlor
Lexone	metribuzin
Lorox, Linex	linuron
Lorox Plus	chlorimuron plus linuron
Marksman	dicamba plus atrazine
Option	fenoxaprop
Poast	sethoxydim
Prelude	paraquat plus metolachlor
Preview	chlorimuron plus metribuzin
Princep, Simazine, Caliber 90	simazine

Prozine .... pendimethalin plus atrazine
Prowl .... pendimethalin
Ramrod .... propachlor
Reflex .... fomesafen
Rescue .... naptalam plus 2,4-DB
Roundup..................................... glyphosate
Salute .... metribuzin plus trifluralin
Scepter.. imazaquin
Sencor .... metribuzin
Sonalan .... ethalfluralin
Squadron .... pendimethalin plus imazaquin
Surflan .... oryzalin
Sutan+, Genate Plus .... butylate plus safener
Sutazine, Rhino .... butylate plus atrazine
Tandem .... tridiphane
Tornado...................... fomesafen plus fluazifop
Treflan .... trifluralin
Tri-Scept.................... trifluralin plus imazaquin
Turbo .... metribuzin plus metolachlor
Vernam .... vernolate

Some herbicides have different formulations and concentrations under the same trade name. *No endorsement of any trade name is implied, nor is discrimination against similar products intended.*

Herbicide combinations

Herbicides are often combined to control more weed species, reduce carryover, or reduce crop injury. Numerous combinations or mixtures of herbicides are sold as premixes, while others are tank-mixed. Tank-mixing allows you to adjust the ratio of herbicides to fit local weed and soil conditions, while premixes may overcome some of the compatability problems found with tank-mixing. If you use a tank-mix, you must follow restrictions on all products used in the combination.

Problems may occur when mixing emulsifiable concentrate (EC) formulations with wettable powder (WP), water-dispersible liquid (WDL), or water-dispersible granule (WDG) formulations. These problems can sometimes be prevented by using proper mixing procedures. Fill tanks at least one-fourth full with water or liquid fertilizer before adding herbicides that are suspended. If using liquid fertilizers, check compatibility in a small lot before mixing a tankful. The addition of compatibility agents may be necessary. Wettable powders, WDGs, or WDLs should be added to the tank and thoroughly mixed before adding ECs. Emulsify ECs by mixing with equal volumes of water before adding them to the tank. Empty and clean spray tanks often enough to prevent accumulation of material on the sides and the bottom of the tank.

The user can apply two treatments of the same herbicide (split application) or can use two different herbicides, provided such uses are registered. The use of one herbicide after another is referred to as a sequential or overlay treatment. Sequential treatment may be done in a number of ways. For example, a preplant application may be followed by a preemergence application, or a soil-applied treatment may be followed by a postemergence treatment. One herbicide may be broadcast, the other banded or directed.

Herbicide rates

Herbicide rates vary according to the time of application, soil conditions, the tillage system used, and the seriousness of the weed infestation. Sometimes lower rates are specified for preemergence application than for preplant incorporated application. Postemergence rates may be lower than preemergence rates if the herbicides may be applied at either time. Postemergence rates often vary depending upon the size and species of the weeds and whether or not an adjuvant is specified. Rates for combinations are usually lower than rates for herbicides used alone.

The rates for soil-applied herbicides usually vary with the texture of the soil and the amount of organic matter the soil contains. For instance, light-colored, medium-textured soils that have little organic matter require relatively lower rates of most herbicides than do dark-colored, fine-textured soils that have medium to high organic-matter content. For sandy soils, the herbicide label may specify "do not use," "use a reduced rate," or "use a postemergence rather than soil-applied herbicide," depending on the herbicide and its adaptation and on crop tolerance.

The rates given in this guide are, unless otherwise specified, broadcast rates for the amount of formulated product. If you plan to band or direct herbicides, adjust the amount per crop acre according to the percent of the area actually treated. Many herbicides have several formulations with different concentrations of active ingredient. Be sure to read the label and make necessary adjustments when changing formulations.

Postemergence herbicide principles

Postemergence herbicides applied to growing weeds generally have foliar rather than soil action; however, some may have both. The rates and timing of applications are based on weed size and climatic conditions. Weeds can usually be controlled with a lower application rate when they are small and tender. Larger weeds often require a higher herbicide rate or the addition of a spray additive, especially if the weeds have developed under droughty conditions. Herbicide penetration and action are usually greater with warm temperature and high relative humidity. Rainfall occurring too soon after application (1 to 8 hours, depending on the herbicide) can cause poor weed control.

Translocated herbicides are most effective at lower spray volumes (5 to 20 gallons per acre), whereas contact herbicides require more complete coverage. Foliar coverage increases as water volume and spray pressure are increased. Spray nozzles that produce small droplets also improve coverage. For contact herbicides, 20 to 40 gallons of water per acre are often recommended for ground application, and a minimum

of 5 gallons per acre is recommended for aerial application. Spray pressures of 30 to 60 psi are often suggested with flat-fan or hollow-cone nozzles to produce small droplets and improve canopy penetration. These small droplets are quite subject to drift.

The use of an adjuvant such as a surfactant, crop-oil concentrate, or fertilizer solution may be recommended to improve spray coverage and herbicide uptake. These spray additives will usually improve weed control but may increase crop injury. Spray additives may be needed, especially under droughty conditions or on larger weeds.

Crop size limitations may be specified on the label to minimize crop injury and maximize weed control. If weeds are smaller than the crop, basal-directed sprays may minimize crop injury because they place more herbicide on the weeds than on the crop. If the weeds are taller than the crop, rope-wick applicators or recirculating sprayers may be used to place the herbicide on the top of the weeds and minimize contact with the crop. Follow the label directions and precautions for each herbicide.

Conservation tillage and weed control

Conservation tillage refers to tillage methods that provide efficient crop production along with adequate control of soil erosion caused by wind and water. Erosion is controlled by protecting the soil surface with plant residue. The amount of tillage is less than that used in conventional moldboard plowing. Chisel plowing, ridge tilling, or no tillage may be used; several other systems are also available.

With reduced tillage systems, there is often a greater reliance upon herbicides for weed control. With these systems, herbicides cannot be incorporated without covering much of the residue that is necessary for effective erosion control. Early applications of preplant, preemergence, or postemergence herbicides are alternatives to incorporation.

Early preplant herbicides may be applied several weeks before planting. Early application may reduce the need for a contact herbicide at planting. However, early preplant application may require additional herbicides (preemergence or postemergence) or cultivation for satisfactory weed control.

Compared with preplant incorporated herbicides, preemergence herbicides require less tillage, but their performance is more dependent upon timely rainfall. Preemergence herbicides, however, have performed better than herbicides that are poorly incorporated. With conservation tillage, a higher application rate of surface-applied herbicides may be required for satisfactory weed control, especially in fields with considerable weed infestation or crop residue. However, do not use a higher rate than that stated on the label. Use great care when selecting herbicides and choosing application rates.

Postemergence herbicides, which are not influenced by crop residues or soil action, may be a logical choice with some conservation tillage systems. Postemergence herbicide rates are generally the same regardless of the tillage system used. However, the effectiveness of postemergence herbicides is greatly influenced by climatic conditions and weed size.

No-till and double-crop

Corn, sorghum, and soybeans may be planted without seedbed preparation, either in last year's crop residue (no-till) or as a second crop after small-grain harvest or forage removal (double-crop). Because it conserves soil, soil moisture, and time, no-till planting has greatly improved the probability of success with double-cropping.

Several precautions should be observed in no-till cropping systems. Crop seed should be planted to the proper depth and adequately covered to avoid possible contact with herbicide sprays. (Several herbicide labels give the planting depths that are necessary to avoid possible injury.) Preemergence applications may give better weed control than preplant applications because the planting process can expose untreated soil that contains viable weed seed. The total reliance on chemical weed control and the large amounts of crop residue present under no-till cropping systems may require that the higher labeled rates of soil-applied herbicides be used to obtain acceptable weed control. However, some phases of a no-till system may require little or no increase in herbicide rates or costs.

Control of existing vegetation in reduced tillage programs

Existing vegetation may be a perennial sod (grass, legume, or legume-grass), an annual cover crop, or weeds. Perennial legume sods often can be controlled before planting corn or sorghum by preplant applications of 2,4-D and Banvel. For shallow-rooted clovers, triazines may give adequate control if moisture is sufficient. But for deeper-rooted alfalfa, on the other hand, 2,4-D and Banvel tanslocate better to the roots. Banvel may be used in the fall (but not in spring) before planting soybeans. Some perennial grass sods can be controlled with Roundup. Fall applications are usually more effective than early spring applications. If a cutting of forages is removed before no-till planting, sufficient regrowth of the forage must occur before herbicides are applied.

Existing vegetation of small annual weeds that are less than 2 inches tall can often be controlled by residual herbicides that have postemergence activity. Bladex, atrazine, Sencor, Lexone, Preview, Lorox, Lorox Plus, and Scepter have both preemergence and postemergence activity. Postemergence activity is often increased by the addition of surfactants or the use of liquid fertilizer as a carrier instead of water.

Early preplant application of labeled residual herbicides can often prevent existing vegetation from being a problem before the crop is planted. Applications that are made too early may need an additional

preemergence or postemergence herbicide application to increase the period of weed control. See the section entitled "Preplant not incorporated" for more information. If the annual vegetation is more than 2 to 3 inches tall, a burndown or translocated herbicide may be needed. Many postemergence herbicides do not have significant residual activity. Gramoxone Super or Roundup is often used with preemergence herbicides to control existing vegetation.

Gramoxone Super (1½ to 2½ pints per acre) plus a *nonionic* surfactant may be used to "knock down" existing foliage before crop emergence. Smartweed, giant ragweed, "marestail," and fall panicum may not be controlled. At least 40 gallons of spray per acre is suggested to ensure adequate coverage of the foliage. Gramoxone Super may be applied with certain liquid fertilizers. *Do not apply* with suspension or high-phosphate liquid fertilizers.

Prelude is a premix of paraquat plus metolachlor (Dual) for preplant use in corn, soybeans, or grain sorghum (which must have Concep II seed treatment).

Roundup (3 to 8 pints per acre) is another alternative for control of existing vegetation before crop emergence in situations where fall panicum, smartweed, or certain perennial weeds are a problem. Roundup can translocate to the roots to give better control of perennials. Use 10 to 40 gallons of spray volume per acre. Roundup plus 2,4-D may be used in some situations to improve broadleaf control.

For control of small annual weeds, Roundup may be used at a rate of 12 to 16 ounces per acre plus 0.5-percent nonionic surfactant in 5 to 10 gallons of spray solution per acre. Do not mix the Microtech formulation of Lasso with Roundup.

Bronco is a formulated mixture of glyphosate (Roundup) plus alachlor (Lasso). Application rates are 4 to 5 quarts per acre. Bronco may be applied in 10 to 30 gallons of water or in 10 to 50 gallons of 28-percent or 32-percent liquid nitrogen solutions. Applications with a nitrogen solution should be made only for control of annual weeds that are less than 6 inches tall.

Roundup, Gramoxone Super, and Bronco are registered for use in combination with the preemergence herbicides indicated in Table 74. See the sections entitled "Herbicides for corn" and "Herbicides for soybeans" for more information about these products.

Banvel may be used in the fall or spring before planting corn to control annual and perennial broadleaf weeds. It is more effective on smartweed than is Gramoxone Super or 2,4-D. Banvel may be used in the fall (*but not in the spring*) before planting soybeans.

2,4-D may be used in the fall or spring before planting corn. It is more effective than Banvel on dandelion. A combination of 2,4-D and Banvel is often appropriate to broaden the spectrum of control and reduce costs. The combination is more effective than Roundup in the spring on alfalfa.

The status of 2,4-D applications in the spring prior to planting soybeans has been somewhat controversial.

Table 74. Registered No-Till Herbicide Combinations

	Alone	Combination			
		Dual	Lasso	Surflan	Prowl
Soybeans					
Amiben	GR	GR	GR	GR	GR
Lorox, Lorox Plus	GBR	GR	GR	GR	G
Lexone, Preview	GBR	GR	GR	GR	G
Scepter	GBR	GR	GR	—	GR
Sencor	GBR	GR	GR	GR	G
Turbo	GR	—	—	—	—
Corn					
Atrazine	GBR	GR	GR	—	—
Bladex	GBR	GR	GR	—	—
Princep	GBR	GR	GR	—	—
Extrazine II	GR	GR	GR	—	—
Atrazine + Princep	GBR	GR	GR	—	—
Bicep	GR	—	—	—	—

Knockdown herbicides:
G = Gramoxone Super (paraquat)
R = Roundup (glyphosate)
B = Bronco = Roundup + Lasso
— = Not registered

Table 75. Registered Herbicide Combinations for Preplant Incorporated (PPI), Preemergence (Pre), or Early Postemergence (EPoE) Application in Corn

	Atrazine	Bladex	Extrazine II	Princep	Atrazine + Princep
PPI only					
Eradicane	1	1	1	1	—
Genate Plus	1	1	1	—	—
Sutan+	1	1	1	1	—
PPI or Pre or EPoE					
Used alone	1,2,3	1,2,3	1,2,3	1,2	1,2
Dual	1,2,3	1,2	1,2	1,2	1,2
Lasso	1,2,3	1,2	1,2	2	—

1 = Preplant incorporated
2 = Preemergence
3 = Early postemergence
— = Not registered

The Sencor label indicates 30 days prior to planting, and the Surflan label indicates that you should not plant any crop for 3 months, or until the chemical has disappeared from the soil. The guidelines regarding use of 2,4-D with Poast have been in a state of flux; users are referred to 2,4-D labels, which may not be very explicit in this regard.

Buctril or Buctril plus atrazine is also a possibility to give early postemergence control of weeds prior to planting corn or up until the time of corn emergence.

Herbicides for corn

Herbicides mentioned in this section are registered for use on field corn. Some are also registered for silage corn. See Table 75 for registered combinations. Herbicide suggestions for sweet corn and popcorn may be found in Circular 907, *1989 Weed Management Guide*

for Commercial Vegetable Growers, which appears in the *'89 Illinois Pest Control Handbook.* Growers producing hybrid seed corn should check with the contracting company or the producer of inbred-seed about tolerance of the parent lines.

Preplant not incorporated

Interest in early preplant application is increasing, especially with the trend toward reduced tillage. Bladex, Banvel, and atrazine have postemergence as well as residual activity. Early weeds such as smartweed can be controlled while they are small, and emergence of other weeds can be curtailed.

With **AAtrex, Dual,** or **Bicep**, preplant surface application may be made using a two-thirds rate as early as 45 days before planting, followed by a one-third rate at planting. A single application may be made within 30 days before planting.

Lariat (alachlor plus atrazine) may be used as a preplant plus preemergence 60/40-percent split application on medium- to fine-textured soils. The preplant application may be made up to 30 days before planting. The rate is 5 to 6 quarts per acre.

Bladex may be applied early preplant at labeled rates; but if Bladex is applied earlier than 15 days before planting, a split application or use of another herbicide at or after planting is suggested. **Extrazine II** may also be applied 15 to 30 days before planting corn.

Banvel (dicamba) applied before planting no-till corn can control emerged and actively growing broadleaf weeds. Use one pint per acre for medium- and fine-textured soils and one-half pint on coarse soils with over 2-percent organic matter. When planting into a legume sod (alfalfa or clover), apply one-half to one pint of Banvel after 4 to 6 inches of regrowth of the legume. A follow-up postemergence treatment may be needed.

Marksman (dicamba plus atrazine) may be used as a preplant treatment in no-till corn. The rate is 3.5 pints per acre on medium- and fine-textured soils that have at least 2-percent organic matter. See the postemergence section for more information.

2,4-D may be used to control existing vegetation in minimum-tillage and no-till situations before planting corn. Many preplant tank-mixes labels allow for 1 to 2 pints of 2,4-D LV ester per acre, but see the specific label for details.

Buctril, or a tank-mix or premix of Buctril plus atrazine, may be used before planting field corn or grain sorghum, up until just before crop emergence to control emerged annual broadleaf weeds. Apply Buctril alone at 1.0 to 1.5 pints per acre, or Buctril mixed with atrazine at 0.5 to 1.2 pounds of active ingredient.

Roundup may be used preplant to corn or sorghum at three-fourths to one pint (12 to 16 fluid ounces) per acre to control small annual weeds. Use 5 to 10 gallons of water per acre plus a nonionic surfactant. Roundup may be mixed with Banvel or 2,4-D.

Preplant incorporated herbicides

Some herbicides may be applied prior to planting and incorporated. The time of application will depend upon the label directions and field conditions. Herbicides with sufficient residual activity may be applied early preplant. If these herbicides are applied too early, however, weed control may not last as long as desired after planting. Incorporation should distribute the herbicide uniformly throughout about the top 2 inches of soil. *Do not apply preplant herbicides too early or incorporate them too deeply.*

Sutan+, Genate Plus (butylate), Eradicane, and Eradicane Extra (EPTC) contain crop safening agents. Crop injury is unlikely but may occur when growing conditions are unfavorable or when certain hybrids are used. Eradicane Extra also contains an extender to lengthen weed control. These herbicides control annual grass weeds and at higher rates can control or suppress some problem grasses. The rate for Sutan+ and Genate Plus is 4¾ to 7⅓ pints per acre. The rate for Eradicane 6.7E is 4¾ to 7⅓ pints per acre. The rate for Eradicane Extra 6E is 5⅓ to 8 pints per acre. Use the higher rates for heavy infestations of shattercane and yellow nutsedge and for johnsongrass.

Application close to planting time is generally preferred to provide the maximum duration of weed control. These herbicides should be incorporated into the soil soon after application, although 4 hours may elapse before incorporation with the high rate and a dry soil.

Sutan+, Genate Plus, Eradicane, or Eradicane Extra may be tank-mixed with atrazine or Bladex to improve broadleaf control. The atrazine rate is 2 to 3 pints of 4L or equivalent amounts of 80W or 90WDG per acre. The Bladex rate is 3 to 4 pints of 4L or 2 to 2½ pounds of 80W per acre. Three-way combinations with atrazine plus Bladex are also registered. These herbicides (either alone or in combination) may be applied with liquid fertilizer or impregnated on dry, bulk fertilizer. Refer to the labels for specific information.

Sutazine and Rhino (butylate plus atrazine) contain different ratios of active ingredients. Sutazine+ 6ME contains 4.8 pounds of butylate and 1.2 pounds of atrazine per gallon. The rate is 5.5 to 10.5 pints per acre. Rhino 6E contains 4.3 pounds of butylate and 1.7 pounds of atrazine per gallon, and the rate is 6.0 to 11.7 pints per acre.

Preplant or preemergence herbicides

Incorporation of the following herbicides is optional, depending upon the weeds to be controlled and the likelihood of rainfall. Incorporation of these herbicides should be shallow but thorough.

AAtrex, Atrazine (atrazine), or Princep (simazine) may be applied anytime during the 2 weeks before planting or soon after planting. If rainfall is limited, incorporation may aid performance. Corn tolerance of atrazine and simazine is good, but carryover to subsequent crops may occur.

Princep controls fall panicum and crabgrass better than atrazine does but is less effective in controlling cocklebur, velvetleaf, and yellow nutsedge. Princep is less soluble and more persistent than atrazine; thus Princep is usually applied preplant. Princep plus atrazine may be used in 1:1 or 2:1 combinations; the total rate is the same as for atrazine used alone.

The rate for atrazine used alone is 2½ to 3¾ pounds of atrazine 80W, 4 to 6 pints of 4L, or 2.2 to 3.3 pounds of AAtrex Nine-0. Atrazine controls annual broadleaf weeds better than it does grasses, and it is often used at reduced rates in tank-mix combinations to improve broadleaf weed control. The rate for atrazine in some combinations is 1½ to 2 pounds of atrazine 80W, 2 to 3 pints of atrazine 4L, or 1.1 to 1.8 pounds of AAtrex Nine-0. These rates may not provide adequate control of cocklebur, morningglory, and velvetleaf but can reduce the risk of carryover.

You can minimize carryover injury by mixing and applying the herbicides accurately, by applying them early, by using the lowest rates consistent with good weed control, and by tilling the soil to dilute the herbicide. The risk of carryover is greater after a cool, dry season and on soils with a pH over 7.3.

If you use atrazine at more than 3 pounds of active ingredient per acre (lb a.i./A) or if you apply after June 10, plant only corn or sorghum the next year. If you use atrazine in the spring and must replant, then plant only corn or sorghum that year. Do not plant small grains, small-seeded legumes, or vegetables in the fall or the following spring. Soybeans planted the year after an application of atrazine can also be affected by carryover, especially if you use Sencor or Lexone.

Bladex (cyanazine) has shorter soil persistence than atrazine, but atrazine has better corn tolerance. Rates of Bladex must be selected accurately on the basis of soil texture and organic-matter content to reduce the possibility of corn injury. The rates per acre for Bladex alone are 1.5 to 6.0 pounds of 80W, 1.35 to 5.3 pounds of 90DF, or 1.25 to 4.75 quarts of 4L. You can lessen the risk of corn injury by using reduced rates of Bladex in combination with other herbicides.

Bladex provides better control of most annual grasses than does atrazine but is weaker than atrazine on several broadleaf weeds, particularly pigweed.

Extrazine II contains cyanazine (Bladex) and atrazine. It is available as 90DF and 4L formulations and can be used preplant incorporated, preemergence, or in tank-mix combinations similar to Bladex. (See Table 75.) Rates must be adjusted carefully to the soil texture and organic-matter content.

Bladex may be tank-mixed with Genate Plus, Sutan+, or Eradicane for preplant incorporation or with Lasso or Dual for preplant or preemergence application. *Bladex and Extrazine II are restricted-use pesticides.*

Lasso (alachlor) or Dual (metolachlor) may be preplant incorporated or applied preemergence at planting time. Preplant incorporation of these herbicides can improve control of yellow nutsedge and can lessen dependence upon rainfall. Incorporation should distribute the herbicide evenly throughout the top 2 inches of soil.

Lasso and Dual control annual grasses and help control yellow nutsedge. You can improve broadleaf weed control by using atrazine, Bladex, or both in either a preplant or a preemergence combination.

Lasso may be applied anytime during the week before planting corn and shallowly incorporated, or it may be used after planting but before the crop and weeds emerge and within 5 days after the last tillage operation. The rate is 2 to 4 quarts of Lasso 4E or 16 to 26 pounds of Lasso 15G per acre.

Dual may be applied and shallowly incorporated within 45 days before planting, or it may be used soon after planting. The rates are 1½ to 4 pints of Dual 8E or 6 to 16 pounds of Dual 25G per acre.

Lasso or Dual plus atrazine may be preplant incorporated or applied after planting until corn is 5 inches tall and grass weeds have not passed the two-leaf stage. *Do not apply with liquid fertilizer after the crop emerges.* The suggested rate is 1½ to 4 quarts of Lasso or 1¼ to 2½ pints of Dual 8E plus 1½ to 2½ pounds of atrazine 80W, 1 to 2 quarts of atrazine 4L, or 1.1 to 2.2 pounds of AAtrex Nine-O per acre. Dual is also cleared in a combination with atrazine plus Princep.

Bicep 6L is a 5:4 premix of metolachlor (Dual) plus atrazine used at 1½ to 3 quarts per acre. **Lariat 4L** is a 5:3 premix of alachlor (Lasso) plus atrazine used at 2½ to 4½ quarts per acre.

Dual or Lasso plus Bladex may be applied before planting and incorporated, or either combination may be applied preemergence at planting. The rate is 2 to 4 quarts of Lasso 4E or 1¼ to 2½ pints of Dual 8E plus 1 to 3¾ pounds of Bladex 80W or 1 to 3 quarts of Bladex 4L per acre. Adjust the rate carefully according to soil texture and organic-matter content.

Preemergence herbicides

Ramrod (propachlor) may be applied alone before the crop or weeds emerge or with atrazine after the corn is planted but before grasses reach the two-leaf stage and corn emerges. Ramrod performs well on soils with more than 3-percent organic matter.

Because Ramrod is irritating to the skin and eyes, observe the label precautions. Corn tolerance is good. Ramrod controls annual grasses and pigweed. The rate is 4 to 6 quarts of Ramrod 4L or 20 to 30 pounds of 20G per acre.

Banvel (dicamba) may be applied immediately after planting, at the rate of one pint per acre on medium- to fine-textured soils having at least 2-percent organic matter. Do not apply preemergence to coarse-textured soils or any soils having less than 2-percent organic matter (4 percent on Lasso label). Banvel may be applied preemergence to early postemergence in tank-mix combinations with atrazine, Bladex, Lasso, Dual, or Prowl. **Marksman** is a premix of dicamba (Banvel)

with atrazine. Refer to the labels for rates, timing, and precautions when using these combinations.

Prowl (pendimethalin) may be used in corn only after planting: do not incorporate. Corn should be planted at least 1½ inches deep. Prowl can control annual grasses, pigweed, and lambsquarters. The Prowl rate is 1½ to 4 pints alone or 1½ to 3 pints in combination with atrazine or Bladex. **Prozine 70DF** is a 1:1 premix of pendimethalin (Prowl) plus atrazine used at 3 to 4¼ pounds per acre. The tank-mixes and premix may be applied after corn emergence but before the crop reaches the four-leaf stage and weeds reach the one-inch stage. Avoid postemergence application when corn is under stress from cool, wet weather. Do not apply postemergence in liquid fertilizer.

Postemergence herbicides

Lasso, Dual, Ramrod, or Prowl may be combined with atrazine for application after planting to very early postemergence. The same is true for Lasso or Dual combined with Banvel. To obtain satisfactory control, apply before grasses reach the two-leaf stage. Early postemergence applications should be made using water, not liquid fertilizer, as a carrier. For more information, see the section on "Postemergence herbicide principles."

Atrazine may be applied when grass weeds are no more than 1½ inches high. Many annual broadleaf seedlings are more susceptible than grass weeds and may be treated until they are 4 inches tall. For control of some broadleaf weeds, 1.2 pounds active ingredient of atrazine may be sufficient. In most cases, this rate should be increased to 2 pounds for control of annual grass weeds.

The addition of oil-surfactant mixes or surfactants has generally increased the effectiveness of postemergence atrazine. Crop-oil concentrates, COCs (80-percent oil and 20-percent surfactant), are used at the rate of one quart per acre.

An atrazine-and-oil mix sometimes injures corn that has been under stress from prolonged cold, wet weather or other factors. Do not use more than 2½ pounds of atrazine 80W, 2 quarts of atrazine 4L, or 2.2 pounds AAtrex Nine-O per acre if you mix with oil or an oil concentrate. *Do not add 2,4-D to the atrazine-oil treatment, or severe injury may result.* Mix the atrazine with water first, and add the oil last. If atrazine is applied after June 10, do not plant any crop except corn or sorghum the next year.

Bladex (cyanazine) may be applied until the fifth leaf of corn is visible and before grass weeds exceed 1.5 inches in height. The rate is 1.5 to 2.5 pounds Bladex 80W or 1.1 to 2.2 pounds Bladex 90DF per acre. *Do not use Bladex 4L postemergence.* Either a tank-mix (Bladex and atrazine) or a premix (Extrazine II) may also be applied postemergence.

Do not apply Bladex alone or with atrazine (tank-mix or premix) postemergence either in cold, wet weather or to corn that is stressed. Injury to corn is more likely under these conditions. Under droughty conditions, certain agricultural surfactants or vegetable oils may be added to Bladex 80W and 90DF. Do not use these spray additives with Extrazine II. Do not use petroleum crop oils or apply Bladex or Extrazine II with liquid fertilizers. Do not apply Bladex or Extrazine II to corn grown for seed. *Bladex and Extrazine II are classified as restricted-use pesticides.*

Tandem (tridiphane) may be used with atrazine, Bladex, or both for postemergence control of both annual grass and broadleaf weeds in field corn. These combinations should be applied when annual grass weeds are in the one- to three-leaf stage and actively growing. The rates per acre are 1 to 1½ pints of Tandem plus 1½ to 4 pints of atrazine 4L (equivalent rates of 80W or 90DF) or 1 to 2½ pounds of Bladex 80W (equivalent rates of 90DF). *Do not use Bladex 4L in combination with Tandem.* Crop-oil concentrate (2 pints per acre) should be used with the tank-mixes that do not contain Bladex. Combinations containing Bladex should not be applied to corn under stress from cold or wet weather, to corn with more than four true leaves, or if rain is expected within 3 hours. Special programs are labeled for control of larger grasses, woolly cupgrass, and wild proso millet. See the Tandem label for more information on these programs.

Banvel (dicamba) may be applied early postemergence when corn is in the spike to five-leaf stage or up to 8 inches tall. The rate is one pint of Banvel per acre on medium- and fine-textured soils or one-half pint on coarse-textured soils. Corn tolerance is better and the potential for drift is less with the early treatment. Banvel may be tank-mixed with Lasso, Dual, Bladex (not 4L), or atrazine and applied early postemergence. See the label for rates, timing, and specific precautions.

Banvel may also be applied at one-half pint per acre to corn more than 8 inches tall but less than 36 inches tall. Weeds should be less than 12 inches tall for best control. Use drop nozzles on corn over 8 inches tall (Banvel alone or with 2,4-D) to improve corn tolerance and improve spray coverage to the weeds. Do not apply Banvel within 15 days of tassel emergence.

Do not apply Banvel where soybeans are growing nearby if corn is more than 24 inches tall, soybeans are more than 10 inches tall, or the soybeans have begun to bloom. Observe all label precautions concerning spray pressure, spray volume, nozzle selection, wind speed, and temperature in order to minimize risk of vapor or spray drift to nearby susceptible crop or ornamental plants.

A preharvest treatment of Banvel plus 2,4-D can help control hemp dogbane. Apply after the brown silk stage in corn but at least 7 days before harvest, at the rate of one-half pint of Banvel with one pound acid-equivalent 2,4-D LV ester or amine per acre if current label covers this application. Nearby soybeans must be fully podded, with leaves turning yellow. The hemp dogbane must have green leaves and roots with

pink buds. Do not apply near homesteads or residential districts.

Marksman is a 1:2 premix of dicamba (Banvel) and atrazine that may be applied when corn is in the spike to five-leaf stage. The rate is 3½ pints per acre on medium- or fine-textured soils that contain over 2-percent organic matter. Marksman may be tank-mixed with Bladex (not 4L), Dual, Lasso, or 2,4-D for very early postemergence application. See the label for rates, timing, and precautions. Drift precautions are the same as with Banvel.

If weeds are drought-stressed, the addition of an approved agricultural surfactant to Banvel or Marksman will improve coverage and control. Do not use adjuvants containing penetrants such as petroleum or crop oils because corn injury can be severe.

2,4-D is effective in controlling many broadleaf weeds in corn. If corn is more than 8 inches tall, use drop nozzles to decrease the possibility of injury to the corn. If you direct the nozzles toward the row, adjust the spray concentration so that excessive amounts are not applied to the corn.

The suggested broadcast rate is one-third to one-half pint of ester or one pint of amine for formulations with 3.8 pounds of 2,4-D acid-equivalent per gallon. Use equivalent rates with other formulation concentrations. Use proportionately less 2,4-D when using directed nozzles.

Do not apply 2,4-D to corn from the tasseling stage to the dough stage. After the hard dough to dent stage, you may apply 1 to 2 pints of certain 2,4-D formulations by air or high-clearance equipment to control some broadleaf weeds that may interfere with harvest or to suppress certain perennial weeds. Do not forage or feed fodder for 7 days after treatment.

The ester forms of 2,4-D can vaporize and injure nearby susceptible plants. This vapor movement is more likely with high-volatile esters than with low-volatile esters. Spray particles of either the ester or the amine form can drift and cause injury.

Corn is often brittle for 7 to 10 days after application of 2,4-D and thus is susceptible to stalk breakage from high winds or cultivation. Other symptoms of 2,4-D injury are stalk bending or lodging, abnormal brace roots, and failure of leaves to unroll. Injury problems are unlikely once corn has reached the brown silk stage.

High temperature and high humidity can increase the potential for 2,4-D injury, especially if corn is growing rapidly. If it is necessary to spray under these conditions, it may be wise to reduce the rate by about 25 percent. Corn hybrids differ in their sensitivity, and the probability of injury increases when corn is under stress.

Buctril (bromoxynil) may be used to control broadleaf weeds in field and silage corn. It is important to treat when the weeds are small. For ground applications, use at least 10 gallons of water per acre, a spray pressure of 30 psi, and flat-fan nozzles.

Buctril will not volatilize and cause the drift injury associated with 2,4-D or Banvel. Under some conditions, Buctril may cause temporary burning of corn leaves. Do not add a surfactant or crop oil to Buctril used alone or in combination.

Buctril 2E rates are 1 to 1½ pints per acre when corn and weeds are in the three- to eight-leaf stage. Buctril may be applied to corn from the three-leaf stage to tassel emergence; if the rate of 1½ pints per acre is used, Buctril cannot be applied until the four-leaf stage. Use the higher rate on larger corn and weeds. Although most annual broadleaf weeds are controlled, larger pigweed and velvetleaf may require the higher rate or a combination with atrazine.

Buctril may be tank-mixed with atrazine 4L at one-half to one quart per acre (or equivalent rates of 80W or 90DF). **Buctril/atrazine 3L** is a 1:2 premix used at 1½ to 3 pints per acre. The rate varies with the size of the corn and weeds. Do not apply before the three-leaf stage of corn or after the corn is 30 inches tall.

Laddok (bentazon plus atrazine) is registered for postemergence broadleaf weed control in corn. Laddok does not control grasses. Corn has good tolerance to Laddok.

Laddok is effective mainly through contact action, therefore, weeds must be thoroughly covered with spray. Laddok rates range from 2.5 to 3.5 pints per acre. Always add UAN (urea ammonium nitrate) solution or an oil concentrate to Laddok. For ground application, use one gallon per acre of UAN solution; and, for aerial application, use one-half gallon per acre. If UAN solution is not used, a nonphytotoxic oil concentrate should be added to the spray tank.

Use the oil concentrate if Canada thistle or yellow nutsedge is to be treated. For ground application, use no more than 2 pints per acre of the oil concentrate; and, for aerial application, use no more than 1 pint per acre.

To suppress Canada thistle, apply 3½ pints per acre of Laddok, applied from the time that plants are 8 to 10 inches tall until the bud stage. A single application of Laddok at 3½ pints per acre can suppress yellow nutsedge.

Laddok provides better control of velvetleaf, annual morningglory, lambsquarters, and pigweed than does Basagran alone and will create less risk of carryover than does atrazine alone.

Basagran (bentazon) may be used alone or with atrazine for postemergence broadleaf weed control in corn. Basagran is cleared for use alone at 1.0 to 1.5 pints per acre or in combination with atrazine at 0.6 to 1.0 pound of 80W, 0.6 to 0.9 pound of 90DF, or 1.0 to 1.5 pints of 4L per acre. Add 28-percent UAN solution (0.5 to 1.0 gallon per acre) or crop-oil concentrate (1 quart per acre) to the spray tank under all conditions. Basagran should be applied when weeds are small and actively growing and when the corn is at the growth stage of one to five leaves. Corn has good tolerance to Basagran.

Roundup (glyphosate) may be applied as a spot treatment in corn prior to silking. For applications

made on a spray-to-wet basis, use a 1- to 2-percent solution of Roundup in water. Avoid contact of spray with the corn.

Postemergence soil-applied herbicides

Some soil-applied herbicides may be applied to the soil as a postemergence treatment in corn. It may be necessary to use drop nozzles to avoid interference from corn leaves and ensure uniform application to the soil.

Prowl (pendimethalin) or Treflan (trifluralin) may be applied to the soil and incorporated after field corn is 4 inches tall (for Prowl) or 8 inches tall (for Treflan) and up to the time of the last cultivation. The field should be cultivated to control existing weeds and cover the roots at the base of the corn before application. The herbicide should then be thoroughly and uniformly incorporated into the top inch of the soil with a sweep-type or rolling cultivator. Prowl may not require incorporation if irrigation is used or rainfall occurs soon after application. Prowl or Treflan may be combined with atrazine.

These Prowl or Treflan treatments may help control late-emerging grasses such as shattercane, wild proso millet, fall panicum, or woolly cupgrass.

Lasso (alachlor) may be used, either alone or with atrazine, as a soil-applied postemergence treatment to help control midseason annual grass weeds in *corn that is grown for seed.* Application should preferably be made after cultivation—before weeds emerge and before the crop is 40 inches tall.

Dual (metolachlor) or Bicep (metolachlor plus atrazine) may be used for postemergence "lay-by" treatments in corn. For Dual, as much as 3 pounds of active ingredient per acre may be used in a single application, up to a total of 6 pounds of active ingredient in one year. With Bicep, as much as 3 quarts of 6L may be used per acre.

Directed postemergence herbicides

Directed sprays are sometimes needed for emergency situations, especially when grass weeds become too tall to be controlled by cultivation. Weeds, however, are often too large for directed sprays to be effective. Directed sprays cannot be used on small corn because a height difference between corn and weeds is needed to keep the spray off the corn. Corn leaves that come into contact with the spray can be killed, and injury can affect yields. *Consider these to be emergency treatments.*

Lorox or Linex (linuron) may be applied as a directed spray after corn is at least 15 inches tall (freestanding) but before weeds are 8 inches tall, preferably when weeds are no more than 5 inches tall. Linuron controls broadleaf and grass weeds.

The broadcast rate is 1¼ to 3 pounds of linuron 50W or 50DF or 1¼ to 3 pints of 4L per acre, depending on weed size and soil type. Add Surfactant WK at the rate of 1 pint per 25 gallons of spray mixture. Cover the weeds with the spray, but keep it off the corn as much as possible.

Evik 80W (ametryn) is registered for directed use when corn is more than 12 inches tall and weeds are less than 6 inches tall. Evik should not be applied within 3 weeks of tasseling. The rate is 2 to 2½ pounds Evik 80W per acre (broadcast) plus 2 quarts of surfactant per 100 gallons of spray mixture. Extreme care is necessary to keep the spray from contacting the leaves.

Gramoxone Super (paraquat) may be applied as a directed spray after corn is 10 inches tall but before weeds are 4 inches tall. The rate is 1½ pint per acre in 20 to 40 gallons of water. Add 1 quart of nonionic surfactant per 100 gallons of spray volume. Control of broadleaf weeds such as smartweed can be improved by adding 1 to 2 pints per acre of atrazine 4L (or equivalent rates of 80W), Bladex, or Princep. Observe all label precautions. *Gramoxone Super is a restricted-use pesticide.*

Herbicides for sorghum

Many herbicides used to control weeds in corn may also be used in sorghum.

Bronco (alachlor plus glyphosate) may be used alone or with atrazine where grain sorghum is to be planted directly into a cover crop or in the residue of the previous crop. Bronco can control emerged annual weeds and may control or suppress many emerged perennial weeds, as well as give preemergence grass control. Grain sorghum seed must be treated with Screen (flurazole), as it is when Lasso is used.

Gramoxone Super (paraquat) can control annual weeds where grain sorghum is to be planted into the residue of the previous crop. **Prelude** (paraquat plus metolachlor) may be used on grain sorghum that has been treated with Concep II. *Gramoxone Super and Prelude are restricted-use pesticides.*

Atrazine may be used for weed control in sorghum (grain and forage types) or sorghum-sudan hybrids, with application made preemergence or postemergence. A preplant surface application may be made using a single application within 30 days of planting or a two-thirds plus one-third split application within 45 days of planting. Plant the seed at least one inch deep. Do not use preplant or preemergence on soils with less than 1-percent organic matter. Atrazine can cause injury to sorghum if rainfall occurs before or shortly after sorghum emergence.

Injury may also occur when sorghum is under stress from unusual soil or weather conditions or when rates are too high. The rate of application for preplant and preemergence is 2 to 3 pounds of atrazine 80W per acre. The postemergence rate is 4 to 6 pints 4L per acre without crop oil or 2.4 pints 4L (broadleaf control only) with crop oil or crop-oil concentrate. Use equivalent rates of atrazine 80W or AAtrex 90DF formulations. Rotational crop recommendations and weed

control are the same as for atrazine used in corn. Failure to control fall panicum has been a major problem.

Ramrod (propachlor) may be used alone or in combination with atrazine or Bladex for sorghum. Ramrod can improve grass control; but rates must not be skimpy, especially on soils that are relatively low in organic matter. Do not graze or feed forage to dairy animals.

Lasso (alachlor) alone or plus atrazine may be preplant incorporated or used preemergence for grain sorghum if seed is treated with Screen (flurazole). This use also applies to Lariat and to Bronco.

Dual (metolachlor) or Bicep (metolachlor plus atrazine) may be used for sorghum if seed has been treated with Concep II. These herbicides will control grasses better than will atrazine applied alone. An early preplant treatment of Dual or Bicep may be used in a similar manner as for corn, but it is still necessary to use seed that has been treated with Concep II.

Basagran (bentazon) is registered for postemergence broadleaf weed control in sorghum in a similar manner as for corn. (See the section entitled "Herbicides for corn.") Because sorghum through the early boot stage is quite tolerant of Basagran, adding a 28-percent UAN solution or crop-oil concentrate is considered relatively safe. Do not apply Basagran to grain sorghum that is heading or blooming.

Laddok (bentazon plus atrazine) is registered for postemergence broadleaf weed control in sorghum in a similar manner as for corn. (See the section entitled "Herbicides for corn.") Adding 28-percent UAN solution or crop-oil concentrate is considered relatively safe. Do not apply Laddok to grain sorghum that is heading or blooming. Laddok use rates range from 2.5 to 3.5 pints per acre.

For best results in sorghum, cultivate 7 to 14 days after application.

2,4-D may be applied postemergence for broadleaf control in sorghum that is from 4 to 24 inches tall. Use drop pipes on nozzles if sorghum is more than 8 inches tall. Rates are similar to those for corn. (See the section entitled "Herbicides for corn.")

Banvel (dicamba) may be applied postemergence to sorghum up to 21 days after emergence but before sorghum is 15 inches tall. The rate is one-half pint per acre. Do not graze or feed treated forage or silage before the mature grain stage. Sorghum can be injured by Banvel, and seed development can be affected.

Buctril (bromoxynil) can control small broadleaf weeds in grain sorghum from the three-leaf up to the boot stage. A tank-mix with atrazine or the Buctril/atrazine mixture may be used. See the label for rates, timing, and weed sizes.

Prowl (pendimethalin) may be applied to grain sorghum from the 4-inch growth stage until the last cultivation, primarily for control of late-season annual grass weeds. For more information, see the subsection on postemergence soil-applied herbicides under "Herbicides for corn."

Roundup (glyphosate) may be applied as a spot treatment in sorghum (milo) prior to heading. For applications on a spray-to-wet basis, use a 1- to 2-percent solution of Roundup in water. With motorized spot treatments from which less complete coverage of weeds may result, use a 5-percent solution. Avoid contact with the sorghum.

Herbicides for soybeans

Consider the kinds of weeds expected when you plan a herbicide program for soybeans, especially when growing soybeans in narrow rows. The herbicide selectivity table lists herbicides and their relative weed control ratings for various weeds. (See the table at the end of this guide.)

Although soybeans may be injured by some herbicides, they usually outgrow early injury with little or no effect on yield if stands have not been significantly reduced. Significant yield decreases can result when injury occurs during the bloom to pod-fill stages. Excessively shallow planting can increase the risk of injury from some herbicides. Accurate rate selection for soil type is essential for herbicides containing metribuzin (Lexone, Preview, Salute, Sencor, or Turbo) or linuron (Linex, Lorox, or Lorox Plus). Do not apply these herbicides after soybeans begin to emerge, or severe injury can result. Always follow label instructions. See Table 76 for some preplant and preemergence tank-mix combinations.

Preplant not incorporated

Early preplant application may be used in many conservation tillage programs — such as no-till, ridge-till, or mulch-till — to minimize existing vegetation problems at planting and thus reduce the need for knockdown herbicides. Lorox or Linex (linuron) and Sencor or Lexone (metribuzin) have both postemergence and residual activity, but postemergence activity varies with climatic conditions. If weeds have emerged before preplant application, the use of a foliar knockdown herbicide such as Gramoxone Super or Roundup may be necessary. (See the subsection about no-till and double-crop programs under "Conservation tillage and weed control.")

Several preemergence herbicides are registered for application before planting soybeans.

Surflan (oryzalin) may be applied anytime before planting no-till soybeans. Surflan may be applied in fully tillered wheat before heading, and soybeans may then be planted no-till into wheat before harvest or in wheat stubble immediately after harvest.

Surflan has been labeled for tank-mixing with 2,4-D prior to 90 days before planting to control established winter weeds for no-till. To control existing vegetation, Gramoxone Super or Roundup combinations with Surflan plus Sencor, Lexone, or Lorox may be applied before planting no-till soybeans. Surflan plus Lexone may be applied as much as 30 days before planting.

Table 76. Registered Herbicide Combinations for Preplant Incorporated (PPI) or Preemergence (Pre) Use in Soybeans

	Treflan	Amiben	Sencor or Lexone	Preview	Lorox or Linex	Sencor + Scepter	Scepter	Sencor + Command	Command	Dual	Lasso
PPI											
Sonalan	—	1	1	1	—	1	1	1	1	—	—
Treflan	—	1	1	1	—	1	1	1	1	1	1
Command	1	—	1	1	—	—	1	—	—	1	1
Salute	—	—	—	—	—	—	1	—	1	—	—
Commence	—	—	1	1	—	—	1	—	—	—	—
PPI or Pre											
Dual	1	1,2	1,2	1,2	2	1,2	1,2	1	1	—	—
Lasso	1	1,2	1,2	1,2	2	1,2	1,2	1	1	—	—
Prowl	—	1,2	1,2	1,2	2	1,2	1,2	1	1	—	—
Surflan[a]	—	2	2	—	2	—	—	—	—	—	—
Turbo	—	—	—	—	—	—	1,2	—	1	—	—

1 = Preplant incorporated
2 = Preemergence
— = Not registered
[a] Not for preplant incorporation

Dual (metolachlor) may be applied within 30 days before planting soybeans or as a split application using a two-thirds rate as early as 45 days before planting, followed by a one-third rate at planting.

Either Turbo alone or Sencor with Lasso or Dual may be applied up to 30 days before planting soybeans when using a sequential (split) preemergence application: the first made early, followed by the second at planting.

Some foliar postemergence herbicides may also be used before planting soybeans.

Roundup (glyphosate) may also be used preplant in soybeans to control small annual weeds. The rate is 12 to 16 fluid ounces (¾ to 1 pint) per acre in 5 to 10 gallons of water, with the addition of a surfactant.

Poast (sethoxydim) may be applied before planting soybeans, with no time interval restriction. Poast plus 2,4-D LV (low-volatile ester) as a tank-mix has been labeled for use before soybean planting. Refer to the most recent label for current registration information and for the specified time period between application and planting. Suggested use rates per acre have been ½ pint of Poast and 1 pint of 2,4-D (½ pound acid-equivalent) with 2 pints of crop-oil concentrate in 5 to 10 gallons of spray solution.

2,4-D has been registered for preplant application to control broadleaf weeds in some no-till programs. Refer to the most recent labels for the current registration and the time interval between application and planting.

Preplant incorporated herbicides

Incorporation is required for Treflan, Sonalan, and Vernam. Incorporation of Command is required to reduce movement outside the target area. Incorporation is optional for Amiben, Dual, Lasso, Preview, Prowl, Sencor, Lexone, and Scepter when used alone or in some combinations. Lorox and Surflan should not be incorporated.

Incorporation improves performance if rainfall is limited and increases the effectiveness of Dual or Lasso in controlling nutsedge. Incorporation should distribute the herbicide evenly in the top 1 to 3 inches of soil. Deep incorporation or very early application of the herbicide can significantly reduce weed control. For more information, see the section entitled "Herbicide incorporation."

Treflan, Prowl, and Sonalan are dinitroaniline herbicides for preplant incorporation before planting soybeans. Treflan and Sonalan must be incorporated, but incorporation is optional with Prowl. However, variable weed control and soybean injury can result if Prowl is not incorporated. See the label for incorporation instructions.

Treflan, Prowl, and Sonalan control annual grasses, pigweed, and lambsquarters, and may provide some control of smartweed and annual morningglory. Prowl partially controls velvetleaf, while Sonalan suppresses black nightshade at the higher rates. Control of most other broadleaf weeds requires combinations (see Table 76) or sequential treatments with other herbicides.

Soybeans are sometimes injured by dinitroaniline herbicides. Plants that have been injured by incorporated treatments may be stunted and have swollen hypocotyls and shortened lateral roots. Usually, such injuries are not serious. At the level of the soil surface, plants injured by preemergence applications may have stem calluses, which can cause lodging and yield loss.

Corn, sorghum, and small grains can be injured if they are grown after a soybean crop that has been treated with a dinitroaniline herbicide. The symptoms are poor germination and stunted, purple plants with poor root systems. To avoid carryover, use no more than the recommended rates of dinitroaniline herbicides and be sure that application and incorporation are uniform. The likelihood of carryover increases with double-cropping or late application and after a cool, *dry season*. Adequate tillage may help dilute herbicide residue, which helps alleviate a carryover problem.

Treflan (trifluralin) may be applied alone anytime in the spring prior to planting. However, tank-mixes

may specify a period closer to soybean planting. Incorporate trifluralin within 24 hours after application, or within 8 hours if the soil is warm and moist. The Treflan rate per acre is 1 to 2 pints 4E or MTF (multiple temperature formulation) — or equivalent rates of Pro-5 or 10G. A slightly higher rate may be specified for shattercane control. A lower rate may be specified in some tank mixtures. Many different herbicides may be tank-mixed with Treflan to improve broadleaf weed control (see Table 76).

Cannon (alachlor plus trifluralin) may be applied at 3 to 5 quarts per acre no more than 7 days prior to planting. Incorporate Cannon into the upper 2 inches of soil within 24 hours after application. For annual grasses only, the rate of 3 quarts per acre is suggested; for fine-textured soils, however, use 4 to 5 quarts per acre. Cannon may be tank-mixed with Command, Lexone, Sencor, Preview, Canopy, or Scepter for additional control of broadleaf weeds.

Sonalan (ethalfluralin) may be applied at 1½ to 3 pints per acre within 3 weeks before planting and should be incorporated within 2 days after application. There is a greater risk of soybean injury from Sonalan than with Treflan, however Sonalan is less likely to carry over and injure corn the following year. Sonalan may be tank-mixed with many herbicides to improve broadleaf control (see Table 76).

Sencor or Lexone (metribuzin) plus Treflan, Sonalan, or Prowl may be tank-mixed and applied within 14 days before planting. Incorporate uniformly into the top 2 inches of soil. The rate of Sencor or Lexone in these combinations is one-half to one pint of 4L or one-third to two-thirds pound of 75DF. Use the usual rate, or slightly less, of the dinitroaniline herbicide (see labels).

The application of Sencor or Lexone may also be split, with one part being incorporated and the other part applied to the surface preemergence. Although this method requires two applications, it can provide better broadleaf control and less injury than incorporating the same total amount of Sencor or Lexone in a single application.

Salute 4E is a premix of trifluralin (Treflan) plus metribuzin used at 1½ to 3 pints per acre. It may be applied up to 3 weeks prior to planting and must be incorporated within 24 hours. Do not apply to coarse soils with less than 1-percent organic matter. Salute may be tank-mixed with Scepter or Command to improve control of certain problem broadleaf weeds.

Command (clomazone) is used at 1½ to 2 pints per acre. It can provide excellent control of velvetleaf and annual grasses. At full rates, Command should also control lambsquarters, smartweed, jimsonweed, and common ragweed. Command may be tank-mixed with Scepter or Preview to improve control of pigweed and cocklebur. Command may also be tank-mixed with Sencor, Lexone, Treflan, Sonalan, Prowl, Lasso, or Dual to improve control of pigweed. See Table 76 for tank-mixes in which Command is used at reduced rates for velvetleaf control.

Commence 5.25L is a premix of Command and Treflan that is used at 1¾ to 2⅔ pints per acre. Commence may be tank-mixed with Preview, Scepter, Sencor, or Lexone.

Command or Commence should be incorporated immediately after application unless the soil is dry, in which case it must be incorporated within 8 hours. Spray particles or vapors drifting outside the target area can cause chlorosis or bleaching of sensitive plants. Do not apply within 100 feet of ornamentals, trees, vegetables, alfalfa, or small grains; within 1,000 feet of subdivisions or towns; or within 1,000 feet of nurseries, greenhouses, and vegetable or fruit production areas.

Do not plant wheat, oats, rye, or alfalfa in the fall or spring of the year following application of Command or Commence. Field corn, sweet corn, popcorn, sorghum, and certain vegetables may be planted 9 months after application of Command or Commence. Refer to the label for restrictions on corn grown for seed. Cover crops may follow, but stand reductions can occur. *Uniform, accurate application and incorporation are needed to minimize risk of carryover.* Some tank-mixes allow reduced rates. Carryover injury will appear as whitened or bleached plants after emergence. Corn may show symptoms early but usually has outgrown them.

Amiben (chloramben) may be incorporated with Treflan, Sonalan, or Prowl. The rate is 4 to 6 quarts of Amiben 2S or 2.4 to 3.6 pounds of 75DS per acre. Amiben may also be applied and incorporated with Treflan or Prowl plus Sencor or Lexone as a three-way combination. However, Amiben alone can control annual grass and several broadleaf weeds, so combinations are not always essential.

Vernam (vernolate) may be applied within 10 days before planting and incorporated immediately. The Vernam rate per acre is 2.3 to 3.5 pints of 7E or 20 to 30 pounds of 10G. Vernam controls annual grasses and pigweed and sometimes provides fair control of velvetleaf, yellow nutsedge, and annual morningglory. Some soybean injury may occur in the form of delayed emergence, stunting, and leaf crinkling. Tank-mixes with Treflan, Prowl, or Sonalan allow the use of a lower rate of Vernam and reduce the risk of injury to soybeans.

Preplant or preemergence herbicides

Prowl (pendimethalin) may be applied before or after planting soybeans. It may be applied up to 60 days preplant alone, 30 days preplant with Scepter, or 7 days preplant with Sencor or Lexone. Preplant treatments should be incorporated within 7 days unless adequate rainfall occurs to incorporate the herbicide. For Prowl used alone, rates are 1 to 3 pints per acre, slightly lower for tank-mixes. Prowl may be applied preemergence in tank-mixes with several herbicides to improve broadleaf weed control (see Table 76). Prowl

can cause stem callousing when applied preemergence, which can lead to soybean lodging.

Lasso (alachlor) or Dual (metolachlor) may be used preplant or after planting to control annual grasses and pigweed. They can also help control yellow nutsedge and black nightshade. They may be combined with Command (preplant incorporated), with Amiben, Lexone, Sencor or Scepter (incorporated or preemergence), or with Lorox (preemergence only) to improve broadleaf weed control.

Lasso may be applied up to one week before planting or after planting but before emergence. Lasso alone may be applied up to the unifoliate stage of soybeans. The Lasso rate is 2 to 4 quarts per acre of 4E or 4L (Microtech), or 16 to 26 pounds of 15G. A slightly lower rate may be specified for combinations.

Dual may be applied early preplant up to 30 days prior to planting or as a split preplant-plus-preemergence application up to 45 days prior to planting. The rate per acre is 1½ to 3 pints of 8E or 6 to 12 pounds of 25G. A slightly lower rate may be specified for combinations.

Amiben (chloramben) can control annual grasses and many broadleaf weeds in soybeans when used at the full rate. Do not expect control of cocklebur or annual morningglory. Control of velvetleaf and jimsonweed is often erratic. See Table 76 for some of the tank-mix combinations. Amiben occasionally injures soybeans, but usually the damage does not affect yield. Injured plants may be stunted and have abnormal, shortened roots. If rain does not occur within 3 to 5 days of an Amiben preemergence application, a rotary hoe should be used over the field. Amiben is best suited to soils that have more than 2.5-percent organic matter.

The broadcast rate for Amiben alone is 20 to 30 pounds of 10G, 4 to 6 quarts of 2S, or 2.4 to 3.6 pounds of 75DS per acre. The Amiben rate in combination is 3 to 6 quarts of 2S (1.8 to 3.6 pounds of 75DS) per acre. Use the higher rate where black nightshade, velvetleaf, or common ragweed is a problem weed.

Sencor or Lexone (metribuzin) may be applied anytime during the 1 to 2 weeks before planting and may be incorporated with Command, Commence, Dual, Lasso, Prowl, Sonalan, or Treflan. Incorporation should distribute the herbicide evenly throughout the top 2 inches of soil. Sencor or Lexone may be applied preemergence by itself or with Amiben, Dual, Lasso, Prowl, or Surflan.

Sencor or Lexone can control many annual broadleaf weeds but does not control annual morningglory. Control of giant ragweed, jimsonweed, and cocklebur is marginal at the reduced rates necessary to minimize soybean injury.

Accurately adjust the rates according to soil conditions. *Do not apply to sandy soil that is low in organic matter.* Combinations allow for reduced rates and thus reduce risk of soybean injury. The combination rate of Sencor or Lexone is one-half to one pint of 4L or one-third to two-thirds pound of 75DF. You can use higher amounts as a split preplant and preemergence application. The higher amounts can improve broadleaf control but also increase the risk of soybean injury.

One symptom of soybean injury is yellowing (chlorosis) of the lower leaves at about the first-trifoliolate stage or later; it may be followed by browning of leaves and death of plants, depending upon the severity of the injury. Seedling diseases, weather stress, and atrazine carryover may increase the possibility of soybean injury. Injury may be greater on soils with a pH over 7.5. Accurate, uniform application and incorporation are essential. Some soybean varieties are more sensitive than others. Injury has sometimes occurred when organophosphate insecticides such as Thimet, Counter, Dyfonate, Lorsban, or Mocap were left in applicators used for corn planting and were then inadvertently applied to soybeans that were being treated with metribuzin.

Turbo 8EC is a premix of metolachlor (Dual) and metribuzin to be applied preplant incorporated or preemergence at the rate of 1½ to 3½ pints per acre. Preplant application may be made up to 14 days before planting. Turbo may be tank-mixed with Scepter or Command to improve control of certain problem broadleaf weeds.

Preview 75DF is a premix of metribuzin (Lexone) and chlorimuron (Classic) used at 6 to 10 ounces per acre. It controls cocklebur, jimsonweed, velvetleaf, and wild sunflower better than metribuzin alone (see the table at the end of this guide). It may be applied preplant incorporated or preemergence. Do not apply after crop emergence. Combinations with other herbicides can improve grass control (see Table 76). *To avoid potential carryover injury, do not apply Preview to soils with a pH greater than 6.8.*

Minimum recropping intervals after application of Preview are 4 months to wheat or barley, 10 months to field corn or alfalfa, and 12 months to grain sorghum or clover. Delay planting another month if application is made after June 15. See the current labeling for climatic effects on recropping. Applying Scepter or Classic the same year as Preview may change the recropping intervals (see the labels).

Scepter (imazaquin) is used at two-thirds pint per acre (one gallon for 12 acres) applied within 30 days before planting or immediately after planting. Incorporation is not required but improves weed control under low-rainfall conditions, and it may also improve control of velvetleaf and giant ragweed. Postemergence application can control cocklebur and pigweed and is made with 0.25-percent surfactant. Do not apply within 90 days of harvest.

Scepter can control most annual broadleaf weeds if adequate rainfall is received but is somewhat weak on control of velvetleaf and annual grasses (see the table at the end of this guide). Grass control is improved by tank-mixing with Prowl, Treflan, Sonalan, Dual, or Lasso.

Squadron 2.33L is a 6:1 premix of pendimethalin

(Prowl) and imazaquin (Scepter) used at 3 pints per acre.

Tri-Scept 3E is a premix of trifluralin and imazaquin in a 6:1 ratio. The rate is 2⅓ pints per acre. It must be incorporated.

Soybeans sometimes show temporary yellowing and growth retardation from applications of Scepter, Tri-Scept, or Squadron. Uniform, accurate application is extremely important to reduce the risk of carryover. If Scepter is incorporated, strive for uniform distribution. Carryover injury to corn appears as stunting, root inhibition, and interveinal chlorosis or purpling of the leaves.

There is significant concern about soil residues of Scepter affecting other, subsequent crops such as corn and wheat. For all of Illinois, do not plant corn grown for seed, sweet corn, or popcorn the year following application of a full rate of Scepter or premixes containing imazaquin (Scepter). If rainfall is adequate, wheat may be planted 4 months or more after application in the major wheat-producing area of southern Illinois. But, generally, other small grains and small-seeded legumes should not follow during the next year.

North of a line extending from Peoria west along State Route 116 and east along U.S. Route 24, do not plant corn, wheat, or small-seeded legumes the year following application — either preplant incorporated or preemergence — of Scepter at the rate of two-thirds pint or its equivalent in Squadron or Tri-Scept.

New labeling may indicate for Illinois south of this line that corn should not follow the next season after the use of two-thirds pint per acre of Scepter (either preplant incorporated or preemergence) when rainfall is limited to 15 inches or less from the time of application until November 1. Such label changes should be considered when making herbicide use and recrop decisions. It is generally not advisable to use Preview, Lorox Plus, or Classic the same year as Scepter because of the increased risk of carryover effects.

Those farm operators who used Scepter or a product containing imazaquin in 1988 should check with their supplier and the most recent labeling for guidelines before planting corn in 1989.

Preemergence herbicides

Surflan (oryzalin) can control annual grasses, pigweed, and lambsquarters if rainfall is adequate. Rotary hoe to control emerging weeds if adequate rain does not fall within 7 days after application. Surflan may be used as an early preplant application for no-till soybeans. Do not use on soils that have more than 5-percent organic matter. The rate is ¾ to 1½ quarts AS per acre (aqueous suspension) used alone and varies in some combinations. Surflan may be tank-mixed with Amiben, Lorox, Lexone, or Sencor to improve control of broadleaf weeds. Surface application may be made within 2 days after planting, prior to emergence. Surflan can cause stem callusing, which can lead to soybean lodging.

Lorox or Linex (linuron) is best suited to silt loam soils that contain 1- to 3-percent organic matter. *Do not apply to very sandy soils.* Linuron controls broadleaf weeds better than grass weeds. It does not control annual morningglory, and control of cocklebur, velvetleaf, and jimsonweed is variable. Accurate, uniform application and proper rate selection are necessary to minimize the risk of crop injury. Tank-mix combinations allow the use of a reduced rate of linuron to decrease the risk of soybean injury, but this reduced rate may also decrease the degree of weed control.

Linuron is registered in tank-mix combinations with Amiben, Lasso, Dual, Prowl, or Surflan to improve grass control. The rate of linuron in these combinations is 1 to 1⅔ pounds of 50DF or 1 to 1⅔ pints of 4L on silt loam soils that have less than 3-percent organic matter.

Lorox Plus 60DF is a premix of linuron (Lorox) plus chlorimuron (Classic) that is used at 12 to 18 ounces per acre. Lorox Plus controls cocklebur, jimsonweed, and velvetleaf better than linuron alone (see the table at the end of this guide). Tank-mixing with Lasso, Dual, Prowl, or Surflan can improve grass control. Lorox Plus should be applied after planting but before soybeans emerge. Do not apply to soils with organic matter less than 0.5 percent.

To minimize potential carryover injury, *do not apply Lorox Plus 60DF to soils with a pH greater than 6.8.* Allow a minimum recropping interval of 4 months to small grains and 10 months to field corn or sorghum. Add one month if application is made after June 15. See the current labeling for climatic effects upon recropping. If applied the same year as Lorox Plus, Scepter will change and Classic may change the recropping intervals (see the current labels).

Postemergence herbicides

Research suggests that soybean yields will probably not be reduced if weeds are controlled within 3 to 4 weeks after the soybeans are planted. Postemergence herbicides are most effective when their use is part of a planned program and when they are applied while the weeds are young and tender; they should not be considered simply as emergency treatments. It is especially important that treatments are timely when using postemergence herbicides in narrow-row soybeans. It is important to know what specific weeds are present in the field and the size of those weeds. Select herbicides and rates accordingly. Usually, smaller weeds are easier to control.

Registered combinations are shown in Table 77. For more information about conditions affecting application, see the section entitled "Postemergence herbicide principles" and refer to labels.

Basagran (bentazon) can control cocklebur, jimsonweed, prickly sida, and velvetleaf; but it is weak on pigweed, lambsquarters, annual morningglory, and

Table 77. **Registered Postemergence Herbicide Combinations for Broadleaf Weed Control in Soybeans**

	Amiben	Basagran	Blazer	2,4-DB	Scepter	Classic
Alanap	X	—	—	X	—	—
Amiben	..	—	X	X	—	—
Basagran	—	..	X	X	X	X
Blazer	X	X	..	X	X	—
Classic	—	—	X	—	—	..
Cobra	—	—	—	X	X	X
Reflex	—	X	—	X	—	—
Rescue	—	—	X	—	—	—
Tackle	—	X	—	X	—	—

X = Registered
— = Not registered

black nightshade. It may be used for control of yellow nutsedge and Canada thistle but does not control annual grasses.

The rate for Basagran is 1 to 2 pints per acre, depending on the weed size and species. Specifics on weed size and rates are indicated on the label. Application, however, preferably should be made when weeds are small (1 to 3 inches tall) and actively growing. These conditions usually exist when the soybeans are in the unifoliolate to second-trifoliolate stage or within 2 to 3 weeks of planting. Spraying during warm, sunny weather can also improve performance. Do not spray if rain is expected within 8 hours. Use at least 20 gallons of water per acre and 40- to 60-psi spray pressure to provide complete weed coverage. The higher spray pressure provides more thorough weed coverage and better control. Adding a crop-oil concentrate (COC) to Basagran may increase performance on most weeds but may cause some soybean injury. The addition of 2 fluid ounces of 2,4-DB (Butyrac 200) to Basagran may help control annual morningglory. Do not add crop oil when mixing with 2,4-DB. Do not mix or apply Basagran with other pesticides or liquid fertilizer except as specified on the product label.

A 28-percent UAN (urea ammonium nitrate) solution—commonly referred to as 28-percent nitrogen solution—may be added to the spray mixture instead of crop-oil concentrate for improved velvetleaf control. The UAN solution may be added to the tank with Basagran plus Blazer or Tackle when velvetleaf is the primary target weed. Do not use brass or aluminum nozzles when spraying Basagran and 28-percent nitrogen solution.

Basagran may be applied as a split application of one pint plus one pint per acre to improve control of lambsquarters, giant ragweed, wild sunflower, and yellow nutsedge. Apply the first pint of Basagran before weeds reach the maximum size or leaf stage as indicated on the label. Apply the second pint 7 to 10 days after the first application.

Blazer or Tackle (acifluorfen) should be applied when broadleaf weeds are in the 2- to 4-inch stage and actively growing. Weeds controlled include annual morningglory, pigweed, jimsonweed, and black nightshade. Control of cocklebur and morningglory can be improved by adding 2 fluid ounces of 2,4-DB. Apply the mixture when cocklebur and morningglory measure no more than 10 or 12 inches. Surfactant addition is recommended when combining Blazer and 2,4-DB, but not with Tackle plus 2,4-DB.

The rate is 1 to 3 pints of Blazer 2L or Tackle per acre. Blazer requires the addition of a nonionic surfactant at a minimum of 1 pint per 100 gallons of spray. Tackle requires the addition of a nonionic surfactant at a minimum of 1 quart per 100 gallons. Tackle may be tank-mixed with 28-percent UAN or 10-34-0 to improve performance on troublesome weeds. Fertilizer solutions may also be added to Tackle plus Basagran and Tackle plus Rescue tank-mixtures. The rate of surfactant may be increased to 2 to 4 pints per acre to improve control of small escaped grasses.

Because Blazer and Tackle are contact herbicides, leaf burn often occurs; however, the crop usually recovers within 2 to 3 weeks. Do not spray if rain is expected within 4 to 6 hours.

Basagran plus Blazer or Tackle provides a means of broadening the spectrum of control because Blazer or Tackle is better on pigweed and annual morningglory, while Basagran is better on cocklebur. The rate is 1 to 2 pints of each product in the combination. Addition of an adjuvant (crop-oil concentrate or surfactant) is suggested. To improve velvetleaf control with Blazer or Tackle plus Basagran, use 28-percent UAN or 10-34-0 liquid fertilizer additives at labeled rates to replace the surfactant or crop-oil concentrate (COC). Do not add COC when using fertilizer additives. A mixture of Blazer plus Basagran plus 2,4-DB amine (2 fluid ounces) may be used to improve control of cocklebur and morningglory under dry weather conditions. Do not add crop-oil concentrate or any other additives when using 2,4-DB with Basagran plus Blazer. Refer to individual product labels for specifics.

Storm 4S and Galaxy 3.67S. Storm is a 2:1 premix and Galaxy a 4.5:1 premix of the active ingredients bentazon (Basagran) and acifluorfen (Blazer). The recommended rate of Storm (1½ pints per acre) is equivalent to 1 pint of Basagran and 1 pint of Blazer. Galaxy at 2 pints per acre is equivalent to 1½ pints of Basagran and ⅔ pint of Blazer.

Storm and Galaxy herbicides are intended for selective postemergence control of broadleaf weeds. They are effective mainly through contact action; therefore, the weeds must be thoroughly covered with spray. Early application makes it easier to obtain thorough spray coverage of weeds and gives better control than later application. Delay in application, which permits weeds to exceed the maximum size stated, will result in inadequate control. Cultivation before or during the application is not recommended. Cultivation may put weeds under stress, thus making control more difficult to obtain.

With Storm or Galaxy, use at least 20 gallons of water per acre and a minimum pressure of 40 psi.

Either crop-oil concentrate or 28-percent UAN should be added to the spray tank with Storm or Galaxy. For

Storm, oil concentrate should be added at a maximum of one pint per acre for ground or aerial application. For Galaxy, oil concentrate should be added at a maximum of 2 pints per acre for ground application or 1 pint per acre maximum for aerial application. The standard use rate of one-half to one gallon of UAN per acre is recommended for ground application of Storm or Galaxy. Check the most recent labels.

Cobra 2E (lactofen) is applied at 12½ fluid ounces per acre with or without crop-oil concentrate (COC) at ½ to 1 pint per acre. Apply Cobra when weeds are small, usually before the four- to six-leaf stage. One gallon per acre of 28-percent UAN may be substituted for COC under favorable growing conditions; or a nonionic surfactant may be used at one quart per acre. Weeds controlled include cocklebur, jimsonweed, pigweed, common ragweed, and black nightshade. Control of annual morningglory and velvetleaf can be enhanced by using the higher rate with COC on weeds with no more than four leaves. Smartweed may be suppressed, but do not expect control of lambsquarters. Cobra can help on burcucumber, copperleaf, prickly sida, ragweeds, tall waterhemp, and venice mallow.

Cobra is a contact herbicide and can cause soybean leaf burn that is intensified at the higher use rate when applied with an adjuvant. The crop usually recovers 2 to 3 weeks after application. Cobra should not be applied if rain is expected within 30 minutes.

Cobra may be tank-mixed with Classic (0.38 to 0.5 ounces per acre), Scepter, or 2,4-DB (2 fluid ounces per acre). Surfactant X 77 is added at 1 quart per 100 gallons of spray solution. Classic improves control of cocklebur, smartweed, and wild sunflower. The 2,4-DB can enhance control of morningglory. Scepter can enhance control of pigweed and cocklebur.

Apply Cobra only once during the season, no later than 90 days before harvest.

Reflex 2LC (fomesafen) may be used to control broadleaf weeds at ¾ to 1 pint, north of Interstate 70, or at 1¼ pints per acre, south of I-70. Use a minimum of 10 gallons of spray per acre and add either crop-oil concentrate at 1 percent (1 quart per 25 gallons) or nonionic surfactant at 0.25 to 0.50 percent by volume. Reflex should control pigweed, black nightshade, jimsonweed, smartweed, and common ragweed up to the four-leaf stage at the high rate. Reflex may be tank-mixed with Basagran at 1 to 2 pints per acre to improve control of velvetleaf and giant ragweed; with 2 to 3 fluid ounces of Butyrac 200 to improve control of annual morningglory, giant ragweed, and cocklebur; or with ½ to ¾ ounce of Classic or ⅓ pint of Scepter to improve cocklebur control. Do not apply Reflex beyond 3 weeks after soybean emergence. It can be tank-mixed with Fusilade or sequentially applied after Fusilade. **Tornado** is a premix of Fusilade plus Reflex. Do not spray if rain is expected within 4 hours of application. *See a current label concerning recrop restrictions.*

Classic (chlorimuron) may be used for postemergence broadleaf weed control at one-half to three-fourths ounce 25DF per acre. Use the higher rate on larger weeds. Use at least 10 gallons of water per acre plus nonionic surfactant at 0.25 percent of spray volume (v/v). Crop-oil concentrate (COC) at 1 percent v/v may replace the surfactant to improve weed control but may increase soybean injury. Classic may cause temporary yellowing and retardation of soybean growth. This will generally be evident 5 to 7 days after application to soybeans that have been under stress. Do not apply Classic if rain is expected within one hour.

Control of cocklebur, jimsonweed, wild sunflower, redroot pigweed, and yellow nutsedge is good. Pigweed control varies with rate and species. Check the label for weed sizes and rates. Velvetleaf control is improved with the use of 28-0-0 (UAN), or 10-34-0 plus COC or surfactant. Split applications approximately 14 to 21 days apart will improve control of burcucumber, giant ragweed, and annual morningglory. Do not apply more than 1½ ounces of Classic 25DF per acre for the season. Do not apply Classic within 60 days of harvest.

Do not apply Classic to soils with a pH greater than 6.8. Allow a minimum recrop interval of 3 months to plant small grains and 9 months to plant field corn, sorghum, alfalfa, or clover. If Classic is applied sequentially after Preview or Lorox Plus, the recrop interval may change (see Classic label). If Scepter is used in the same season as Classic, the recrop interval does change. Carryover injury to corn is possible and may appear as stunting, root inhibition, and interveinal chlorosis or purpling of leaves.

Amiben (chloramben) may be used for postemergence application on soybeans in the cracking to fourth-trifoliolate stage, but only within 33 days after planting. This treatment can be especially helpful in controlling velvetleaf; but smartweed, common ragweed, and pigweed may also be controlled or suppressed. Velvetleaf may be 1 to 8 inches tall, and the others may be 1 to 3 inches tall. For ground applications, 10 to 20 gallons of water per acre, a spray pressure of 30 psi, and flat-fan nozzle tips are suggested. Use 6 quarts of Amiben 2S or 3.6 pounds of Amiben 75DF plus 1 quart of crop-oil concentrate per acre. Amiben may be tank-mixed with Butyrac 200, Alanap, or Blazer, and applied postemergence. See the Amiben label for specific information.

Rescue (naptalam plus 2,4-DB) may be used for midseason to late-season postemergence control of cocklebur, giant ragweed, and wild sunflower; it may also suppress annual morningglory. Apply 2 to 3 quarts per acre after soybeans are about 14 inches tall or after first bloom. Rescue may be tank-mixed with Blazer (1 to 1½ pints per acre) or Tackle (1 pint per acre) to improve control of morningglory, jimsonweed, pigweed, and common ragweed and to provide faster knockdown of weeds. Crop-oil concentrate or a nonionic surfactant should be added at the manufacturer's recommended rate. Fertilizer solutions may be used as spray adjuvants; for example, 10-34-0, may be used

at one quart per acre, or 28-percent UAN is also effective. Tackle is labeled for use with either a nonionic surfactant, crop-oil concentrate, or 28-percent UAN. The water volume per acre is 10 to 25 gallons for ground application and at least 5 gallons for aerial application.

If rain occurs within 6 hours, effectiveness may be reduced. Activity may not be very noticeable until 10 to 14 days after application; maximum activity should occur 20 to 30 days after application. Crop injury such as leaf twisting and terminal droop may occur. To avoid possible yield losses, do not apply Rescue to soybeans under stress from drought, disease, or injury from another herbicide. *Do not apply Rescue within 60 days of harvest.*

Scepter (imazaquin) may be used postemergence in soybeans, primarily for control of pigweed and cocklebur. A Scepter rate of one-third pint per acre may be adequate and can reduce the risk of residual effects on subsequent crops if applied uniformly and accurately, sufficiently early in a season with adequate rainfall. However, certain recrop restrictions may still apply.

Assure (quizalofop) can control a broad spectrum of annual and perennial grasses in soybeans. At 10 ounces per acre, Assure is quite effective on volunteer corn that is 6 to 18 inches tall. The same rate is used for shattercane 6 to 12 inches tall. For giant foxtail that is 2 to 8 inches tall, use 14 ounces of product per acre. Fall panicum, volunteer wheat, and sandbur may be treated when they are 2 to 6 inches tall with 14 ounces per acre. Assure is also effective on wild proso millet and woolly cupgrass.

Add crop-oil concentrate or nonionic surfactant when using Assure. Use at least 10 gallons of water for ground application or 3 gallons for aerial application. Do not apply if rain is expected within an hour. Avoid drift to highly sensitive crops such as corn, sorghum, and wheat. Do not apply within 80 days of harvest, and do not apply after pod set. Do not rotate to crops other than soybeans for 120 days.

If Assure is mixed with Basagran or Classic, increase the rate of Assure by 4 ounces. It is best to use a postemergence herbicide for broadleaf weeds first and then wait about 7 days before applying Assure.

For spot spraying, use 1.0 fluid ounce (2 tablespoons) of Assure and 1.25 fluid ounces (2.5 tablespoons) of crop-oil concentrate or 0.3 fluid ounce (2 teaspoons) of nonionic surfactant.

Poast (sethoxydim) can control many annual and some perennial grasses in soybeans. Apply three-fourths pint per acre to control giant or green foxtail, barnyardgrass, and fall panicum up to 4 inches tall and volunteer corn up to 12 inches tall, or one pint per acre on grasses up to 8 inches tall. Use one-half pint per acre for wild proso millet that is 4 to 10 inches tall. Apply 1½ pints per acre as a rescue treatment if grasses are actively growing (see label for species and sizes). Always use 2 pints per acre of crop-oil concentrate or Dash (special adjuvant) with Poast. Fertilizer additives are recommended for volunteer corn and volunteer cereals. Volunteer cereals less than 6 inches tall (not tillered or overwintered) can be controlled with 1½ pints per acre.

The addition of 28-percent UAN (one gallon per acre) or spray-grade ammonium sulfate (2½ pounds per acre) may improve grass control. Components should be added slowly, with agitation, in the following sequence: (1) fertilizer additive, (2) Dash or crop-oil concentrate, and (3) Poast. After using fertilizer additives, rinse the entire spray system with water to reduce corrosion.

The spray volume is 5 to 20 gallons per acre for ground applications or at least 5 gallons per acre for aerial applications. Lower volumes often result in more consistent grass control. Use only standard high-pressure, hollow-cone, or flat-fan nozzles at 40 to 60 psi. Do not cultivate within 5 days before or 7 days after application. Do not apply Poast to grasses under stress from hot, dry weather or herbicide injury. Do not apply if rainfall is expected within one hour.

Poast plus Basagran may be tank-mixed. If Dash (one quart per acre) plus 28-percent UAN solution (one gallon per acre) are used, the rate of Poast is one pint per acre. Use 1½ pints of Poast per acre if crop-oil concentrate (COC) is used. Apply the tank-mix before broadleaf or grass weeds exceed maximum specified sizes. Tackle may also be added at 1½ to 2 pints per acre, or Blazer may be added.

Poast plus Blazer or Tackle may be tank-mixed. Use one pint of Poast for fall panicum or giant foxtail that is 3 to 8 inches tall. For other annual grasses listed on the Poast label use 1½ pints per acre. For the combination, the rate for Blazer is 1½ to 2 pints per acre, while the rate for Tackle is 1½ to 3 pints per acre. Use crop-oil concentrate (at one quart per acre) and not fertilizer additives with this tank-mix. Sequential application is necessary for perennials and may be more economical for control of annuals.

Fusilade 2000 (fluazifop-P) may be used for postemergence control of annual and perennial grass weeds in soybeans. Apply only to actively growing grasses before they tiller. The rate is 1½ pints per acre when giant foxtail is 2 to 6 inches tall and other annual grass weeds are 2 to 4 inches tall. Use three-fourths pint per acre when volunteer corn is 12 to 24 inches tall, shattercane is 6 to 12 inches tall, or wild proso millet is 6 to 12 inches tall. For control of volunteer cereals, apply one pint per acre before plants are 2 to 6 inches tall. To control wirestem muhly, apply 1½ pint per acre when plants are 4 to 12 inches tall. Fusilade can also control johnsongrass and quackgrass, but sequential applications may be needed. (See the section entitled "Specific weed problems.")

The spray volume should be at least 10 gallons per acre for ground application and 5 gallons per acre for aerial application. Add either crop-oil concentrate at 1 percent by volume (1 gallon per 100 gallons of spray) or a nonionic surfactant at 0.25 percent of spray volume. For aerial application, add one pint of crop-

oil concentrate or surfactant per acre. Apply before soybeans bloom. A tank-mix of Fusilade with Reflex, Tackle, or Blazer is labeled for use. Sequential applications of Fusilade with Basagran, Blazer, Tackle, or Classic are also approved. *Do not tank-mix Fusilade with other postemergence herbicides intended for control of broadleaf weeds except as specified.*

Option (fenoxaprop) may be used postemergence at 0.8 pint plus 1 quart of crop-oil concentrate per acre when giant foxtail is 3 to 6 inches tall or volunteer corn is 10 to 26 inches tall. Use 1.2 pints per acre for 3- to 6-inch tall barnyardgrass or fall panicum. Wirestem muhly (3 to 6 inches tall) or johnsongrass (10 to 16 inches) can be controlled with 1.2 pints per acre. Repeat application may be necessary for control of johnsongrass. Crop-oil concentrate is required for the control of wirestem muhly, yellow foxtail, and crabgrass; is optional for the control of shattercane or johnsongrass seedlings; and should not be used for rhizome johnsongrass control. Rainfall within one hour of application may reduce grass control. Option may be tank-mixed or applied sequentially with Basagran, Blazer, or Tackle.

Roundup (glyphosate) may be applied through several types of selective applicators—recirculating sprayers, wipers, or rope-wicks. This application is particularly useful for control of volunteer corn, shattercane, and johnsongrass. Roundup may also suppress hemp dogbane and common milkweed. Weeds should be at least 6 inches taller than the soybeans. Avoid contact with the crop. Equipment should be adjusted so that the lowest spray stream or wiper contact is at least 2 inches above the soybeans. For equipment calibration, refer to the Roundup label. For recirculating sprayers and wipers, use the rates given on the label. For rope-wick applicators, mix 1 gallon of Roundup in 2 gallons of water. A spot treatment with Roundup is also a good option in many fields. For application made on a spray-to-wet basis, use a 1- to 2-percent solution of Roundup in water. For motorized spot treatments in which coverage of weeds may be less than complete, use a 5-percent solution. Avoid contact of the spray with the soybeans. Add a dye for increased visibility.

Soybean harvest aid

Gramoxone Super (paraquat) may be used for drying weeds in soybeans just before harvest. For indeterminate varieties of soybeans (most of the varieties planted in Illinois), apply when 65 percent of the seed pods have reached a mature brown color or when seed moisture is 30 percent or less. For determinate varieties, apply when at least one-half of the leaves have dropped and the rest of the leaves are turning yellow.

The rate is 11 to 21 ounces of Gramoxone Super per acre. Use the high rate on cocklebur. The total spray volume per acre is 2 to 5 gallons for aerial application and 20 to 40 gallons for ground application. Add 1 quart of nonionic surfactant per 100 gallons of spray. Do not pasture livestock within 15 days of treatment, and remove livestock from treated fields at least 30 days before slaughter.

Specific weed problems

Yellow nutsedge

Yellow nutsedge is a perennial sedge with a triangular stem. It reproduces mainly by tubers, which begin sprouting about May 1 in central Illinois. For the most effective control, soil-applied herbicides should be incorporated into the top 2 inches of the soil.

For soybeans, a delay in planting until late May allows time for two or three tillage operations to destroy many nutsedge sprouts. These operations help deplete food reserves in nutsedge tubers. Row cultivation is helpful. Preplant-incorporated applications of Dual, Lasso, or Vernam will also help.

Lasso (alachlor) preplant incorporated at 1½ to 4 quarts per acre can often give good control of nutsedge.

Dual (metolachlor) may be applied at the rate of 2 to 3 pints per acre to control nutsedge. Preplant incorporated treatment is preferred to treatment at the preemergence stage.

Vernam 6.7E (vernolate) applied preplant at 3½ pints per acre is effective against yellow nutsedge. Immediate incorporation is necessary with Vernam.

Basagran (bentazon) applied postemergence can also help control nutsedge in soybeans. When nutsedge is 6 to 8 inches tall, three-fourths to one quart per acre may be applied. If needed, a second application may be made 7 to 10 days later. The addition of 28-percent UAN or a crop-oil concentrate improves Basagran performance.

Classic, at one-half to three-fourths ounce of product, can provide some control when nutsedge is 2 to 4 inches tall.

For corn that is planted relatively early, preplant tillage before nutsedge sprouts is of little help in controlling nutsedge. Timely cultivation gives some control, but a program of herbicides plus cultivation has provided the most effective control of nutsedge.

Several preplant treatments are available. **Eradicane Extra** at 5⅓ to 8 pints or **Eradicane, Sutan+**, or **Genate Plus** at 4¾ to 7⅓ pints per acre is effective for control of yellow nutsedge in corn. Any of these products should be incorporated immediately. **Lasso** or **Dual** applied in corn at the same rates as for soybeans can also be quite effective.

The combinations of Lasso, Dual, Sutan+, Genate Plus, Eradicane, or Eradicane Extra incorporated with atrazine may improve control of nutsedge while also controlling broadleaf weeds.

Bladex (cyanazine) or **atrazine** may be used as a postemergence spray to control emerged yellow nutsedge when it is small. Split applications of atrazine plus crop-oil concentrate (COC) have been more effective than single applications. **Basagran** may be used in corn in a manner similar to that for soybeans. **Lorox**

or Linex (linuron) as a directed postemergence spray has also given some control.

Johnsongrass

Johnsongrass can reproduce both from seeds and by rhizomes. Both chemical and cultural methods are required to control johnsongrass rhizomes.

Much of the rhizome growth occurs after the johnsongrass head begins to appear. Mowing, grazing, or cultivating to keep the grass less than 12 inches tall can reduce rhizome production significantly.

Control of johnsongrass can also be improved with tillage. Fall plowing and disking bring the rhizomes to the soil surface, where many of them are winter-killed. Disking also cuts the rhizomes into small pieces, making them more susceptible to chemical control.

Johnsongrass rhizomes may be controlled or suppressed with the use of certain herbicides in various cropping programs. Several herbicides can provide control of johnsongrass seedlings in soybeans or corn. (See the table at the end of this guide.)

Treflan (trifluralin) or Prowl (pendimethalin) used in a 3-year soybean program has been fairly successful in controlling rhizome johnsongrass. Either one may be used at 1½ to 2 times the normal rate for 2 years; in the third year, either it is used at the normal rate or another suitable herbicide is used before a regular cropping sequence is resumed. Thorough preplant tillage and incorporation are necessary for satisfactory control. Be certain not to plant crops such as corn or sorghum the year following application of these herbicides at the higher rates.

Fusilade 2000 (fluazifop-P) can control 8- to 18-inch tall johnsongrass. Apply 1½ pints per acre before the boot stage of growth. If new shoots or regrowth occur, make a second application of one pint per acre when johnsongrass is 6 to 12 inches tall. Add crop-oil concentrate at 1 percent of volume or add nonionic surfactant at 0.25-percent volume.

Assure can control johnsongrass from seed or rhizomes. Applying 10 ounces of product per acre is recommended when seedling johnsongrass is 2 to 8 inches tall. For rhizome johnsongrass, apply 26 ounces of product per acre when johnsongrass is 10 to 24 inches tall. If regrowth occurs, a second 14-ounce application may be made when johnsongrass is 6 to 10 inches tall.

Poast (sethoxydim) can control 15- to 25-inch tall johnsongrass in soybeans. Apply 1½ pints of Poast plus 1 quart of Dash or crop-oil concentrate and 1 gallon of 28-0-0 (UAN) or 2½ pounds of ammonium sulfate per acre. A spray volume of 5 to 10 gallons per acre is suggested for best control. If regrowth occurs, apply one pint of Poast per acre when johnsongrass is 6 to 12 inches tall.

Option (fenoxaprop) can control 10- to 25-inch tall johnsongrass in soybeans. Apply 19 fluid ounces of Option per acre when johnsongrass is 10 to 20 inches tall. Do not add crop-oil concentrate.

Eradicane Extra can help control rhizome johnsongrass in corn when used at a rate of 8 pints per acre with a tillage program; Eradicane 6.7E or Sutan 6.7E can provide partial control (suppression) at 7⅓ pints per acre.

Roundup (glyphosate) may be used as a spot treatment to control johnsongrass in corn, soybeans, or sorghum. Apply a 1-percent solution when johnsongrass has reached the boot to head stage and is actively growing. Use of Roundup in rope-wick applicators or recovery-type sprayers is effective for control of johnsongrass in soybeans.

Roundup may be applied in small-grain stubble when johnsongrass is in the early head stage. Fall applications should be made before the first frost. At least 7 days should be allowed after treatment before tillage.

Quackgrass

Quackgrass is a perennial grass with shallow rhizomes. In Illinois, it is found primarily in the northern part of the state.

Atrazine is quite effective when used as a split application in corn. Apply 2 quarts of atrazine 4L per acre in the fall or spring and plow 1 to 3 weeks later. Apply another 2 quarts per acre as a preplant or preemergence treatment. Postemergence application is usually less effective. A single treatment with 3 to 4 quarts per acre may be applied either in the spring or fall 1 to 3 weeks before plowing, but the split application usually gives better control of annual weeds. Use equivalent rates of other formulations. If more than 3 pounds of atrazine active ingredient is applied per acre, plant no crops other than corn or sorghum the next year.

Eradicane Extra may be used to suppress quackgrass in corn if more flexibility in cropping sequence is desired. A rate of 5⅓ pints per acre of Eradicane Extra may be used on light infestations, while 8 pints per acre is suggested for heavier infestations. Some risk of injury to corn occurs, especially at the higher rate. A tank-mix with atrazine should improve control. If Eradicane 6.7E is used, the rate range is from 4¾ to 7⅓ pints per acre for suppression.

Fusilade 2000 (fluazifop-P) may be used for quackgrass control in soybeans at 1½ pints per acre. Apply when quackgrass is 6 to 10 inches tall. If regrowth occurs, a second application of one pint per acre may be made. Best results are obtained with Fusilade and most other treatments if rhizomes are cut up by preplant tillage to stimulate maximum emergence of grass shoots. Always add crop-oil concentrate or nonionic surfactant to Fusilade.

Assure is quite effective for control of quackgrass, with 20 ounces per acre applied when quackgrass is 6 to 10 inches tall. If needed, a second application of 14 ounces may be made when quackgrass is 6 to 10 inches tall.

Poast (sethoxydim) may be used in soybeans to

control quackgrass that is 6 to 8 inches tall. Use 2½ pints of Poast plus 1 quart of Dash or crop-oil concentrate per acre. Always add 28-percent UAN or ammonium sulfate for best control. If regrowth occurs or new plants emerge, apply one pint per acre of Poast when the grass is 6 to 8 inches tall.

Roundup (glyphosate) may be used for controlling quackgrass before planting corn, sorghum, or soybeans. Apply 1 to 3 quarts per acre when quackgrass is 8 inches tall and actively growing (fall or spring). For annual cropping systems, apply 1 quart per acre in 5 to 10 gallons of spray with surfactant added. Delay tillage for at least 3 days after application.

Wirestem muhly

Wirestem muhly is primarily a problem in northern and western Illinois. It is a perennial that reproduces by seeds and scaly rhizomes. The rhizomes are often moved by chisel plows, field cultivators, and shovel cultivators. Many farmers report that delayed seedbed preparation, where possible, can provide some control of wirestem muhly; but wirestem muhly does not start growth until late spring.

Roundup (glyphosate) may be used early preplant (early June) or after harvest when wirestem muhly is at least 8 inches tall and actively growing. Do not till before fall or spring applications. The rate is 1 quart of Roundup in 5 to 10 gallons of water per acre, with surfactant added at 2 to 4 quarts per 100 gallons. Use flat-fan nozzles. After applying, wait 3 days before tilling.

Fusilade (fluazifop) may be used to control wirestem muhly in soybeans. The rate is 1½ pints per acre when wirestem muhly plants are 4 to 12 inches tall.

Assure is effective for control of wirestem muhly, with 16 ounces per acre applied when muhly is 4 to 8 inches tall. If needed, a second application of 14 ounces may be made when muhly is 4 to 8 inches tall.

Poast (sethoxydim) can control 6-inch wirestem muhly in soybeans. Use 1½ pints per acre plus 1 quart of either Dash or crop-oil concentrate per acre. The addition of 28-percent UAN or ammonium sulfate will improve control.

Option (fenoxaprop) can control 3- to 6-inch wirestem muhly in soybeans. Use 1.2 pints plus 1 quart of crop-oil concentrate per acre.

Canada thistle

Canada thistle is a perennial weed that has a large amount of food reserves in its root system. Canada thistle has several varieties, which differ not only in appearance but also in their susceptibility to herbicides.

2,4-D may give fairly good control of some strains. Rates will depend on where the thistle is growing. For example, higher rates may be used in grass pastures or in noncrop areas than may be used in corn.

Banvel (dicamba) often is a little more effective than 2,4-D and may be used alone or in combination with 2,4-D. Banvel may be used as an after-harvest treatment in wheat, corn, or soybean fields and is labeled for use in fallow fields. Rates vary from 1 to 2 quarts of Banvel, alone or in tank-mix combinations with 2,4-D or Roundup. Fall treatments should be applied before killing frosts. For best results, thistles should be fully emerged and actively growing. Fields treated in the fall with Banvel may be planted to corn, sorghum, or wheat the next season; soybeans may be planted if rates of fall-applied Banvel are not excessive.

Atrazine and oil that are applied postemergence have been fairly effective in controlling Canada thistle in corn. Make the application before thistles are 6 inches tall.

Buctril plus atrazine can provide partial control of Canada thistle if applied when the thistles are at the 8-inch to bud stage of growth. Apply Buctril at the rate of one pint per acre plus atrazine at 1.2 pounds of active ingredient per acre; or apply Buctril at 1.5 pints of Buctril plus atrazine at 0.5 to 1.5 pounds of active ingredient per acre.

Basagran (bentazon) may be used for control of Canada thistle in soybeans or corn when the thistles are 8 to 12 inches tall. Apply three-fourths to one quart per acre in a single application; or, for better control, make two applications of three-fourths to one quart per acre each, 7 to 10 days apart. Laddok is effective in corn.

Roundup (glyphosate) may be used at 2 to 3 quarts per acre when Canada thistle is at or beyond the early bud stage. Fall treatments must be applied before frost for best results. After applying Roundup, allow at least 3 days before tillage.

Additional information

Not all available herbicides and herbicide combinations are mentioned in this guide. Some are relatively new and are still being tested. Some are not considered to be well adapted to Illinois or are not used very extensively. For additional information about field crop weed control, consult your county Extension adviser or write to the Department of Agronomy, University of Illinois at Urbana-Champaign, N-305 Turner Hall, 1102 South Goodwin Avenue, Urbana, Illinois 61801.

Table 78. Relative Effectiveness of Herbicides on Major Weeds

This table gives a general comparative rating. Under unfavorable conditions, some herbicides rated good or fair may give erratic or poor results. Under very favorable conditions, control may be better than indicated. Type of soil is also a very important factor to consider when selecting herbicides. Rate of herbicide used also will influence results. G = good; F = fair or variable, and P = poor.

	Grasses									Broadleaf weeds										
	Crop tolerance	Foxtail	Barnyardgrass	Crabgrass	Fall panicum	Johnsongrass seedlings	Shattercane	Volunteer corn	Yellow nutsedge	Annual morningglory	Cocklebur	Jimsonweed	Lambsquarters	Nightshade, black	Pigweed	Ragweed, common	Ragweed, giant	Smartweed	Sunflower, wild	Velvetleaf
SOYBEANS																				
Preplant																				
Command	G	G	G-F	G	G	F	F	P	P	P	P-F	F	G	P	P	F-G	P	F	P	G
Commence	F-G	G	G	G	G	G	G	F	P	P	P-F	F	F	P	G	F	P	F	P	G
Sencor[2], Lexone + dinitroaniline	F	G	G	G	G	G	G	F	P	P-F	F-P	F-G	G	P	G	F	F	G	F	F-G
Treflan, Sonalan	F-G	G	G	G	G	G	G	F	P	P-F	P	P	G	P-F	G	P	P	P-F	P	P
Vernam	F	G	G	G	G	G	G	P-F	F	P-F	P	P	F	P	G	P	P	P	P	F
Preplant or preemergence																				
Amiben	F-G	G	F-G	F-G	F-G	F	F	P	P	P	P	P-F	G	F-G	G	F-G	F	F-G	P	F
Lasso, Dual	G	G	G	G	G	P-F	P-F	P	F-G	P	P	P	F	F-G	G	P-F	P	P-F	P	P
Lasso or Dual + Lorox[1], Linex[1]	F	G	G	G	G	P	P	P	P-F	P	F	F	G	F-G	G	F-G	F	G	F	F
Lasso or Dual + Sencor[3] or Lexone	F	G	G	G	G	P	P	P	F	P	F-P	F-G	G	F-G	G	F	F	G	F	F-G
Lorox[1], Linex[1]	F	F	F	F	F	P	P	P	P	P	F	F	G	F	G	F-G	F	G	F	F
Lorox Plus	F-G	F	F	F	P	G	G	P	P	F	G	G	G	F	G	F-G	F-G	G	F-G	F
Preview	F-G	F	F	F	P	P	P	P	F	F	G	G	G	F-P	G	F-G	F-G	G	G	F-G
Scepter	G	F-G	F	F	P-F	F	F	F	F	F	G	F	G	F-G	G	G	F-G	G	G	F
Scepter + Lasso or Dual	G	G	G	G	G	F	F	F	F-G	F	G	F	G	G	G	G	F-G	G	G	F
Scepter + Prowl[4], Treflan, or Sonalan	G	G	G	G	G	G	G	F	F	F	G	F	G	F-G	G	G	F-G	G	G	F
Sencor, Lexone	F	F	F	F	F	P	P	P	P	P	F-P	F-G	G	P	G	F-G	F	G	F	F-G
Surflan[1], Prowl	F-G	G	G	G	G	G	G	F	P	P-F	P	P	G	P	G	P	P	P-F	P	P-F
Postemergence																				
Assure, Fusilade, Option, Poast	G	G	G	G	G	G	G	G	P	P	P	P	P	P	P	P	P	P	P	P
Basagran	F-G	P	P	P	P	P	P	P	F	P-F	G	G	F-P	P	P	F	F-G	G	G	F-G
Blazer, Tackle	F	P-F	P	P-F	P	P	P	P	P	F-G	F	G	F-P	F-G	G	F-G	F	G	F	P-F
Classic	F-G	P	P	P	P	P	P	P	F	F	G	G	P	P	F-G	F	F	G	G	F
Cobra	F	P	P	P	P	P	P	P	P	F	F-G	G	F-P	F-G	G	F-G	F-G	F-P	F	F
Reflex	G	P-F	P	P	P	P	P	P	P	F	F	G	F-P	F-G	G	F-G	F	F-G	F	P-F
Rescue	F-G	P	P	P	P	P	P	P	P	F	G	F	F-P	P	F-G	P	G	P	G	P
Storm, Galaxy	F-G	P	P	P	P	P	P	P	F	F-G	G	G	F-P	F-G	G	F-G	F-G	G	G	F-G
2,4-DB	P-F	P	P	P	P	P	P	P	P	F-G	G	P-F	F	P	F	F	F	P	F	P

[1] Do not use for preplant incorporation.
[2] Salute = Sencor + Treflan
[3] Turbo = Sencor + Dual
[4] Squadron = Prowl + Scepter

Table 78. Relative Effectiveness of Herbicides on Major Weeds (continued)

	Grasses								Broadleaf weeds										
	Crop tolerance	Foxtail	Barnyardgrass	Crabgrass	Fall panicum	Johnsongrass seedlings	Shattercane	Yellow nutsedge	Annual morningglory	Cocklebur	Jimsonweed	Lambsquarters	Nightshade, black	Pigweed	Ragweed, common	Ragweed, giant	Smartweed	Sunflower, wild	Velvetleaf
CORN																			
Preplant																			
Butylate, EPTC	F-G	G	G	G	G	F-G	F-G	F-G	P	P	P	P-F	F	G	P	P	P	P	F
Butylate, EPTC + atrazine, Bladex	F-G	G	G	G	G	F-G	F-G	F-G	F-G	F-G	G	G	G	G	G	F	G	F-G	F-G
Princep + atrazine	G	F-G	F-G	F	F	P-F	P-F	P	F-G	F-G	G	G	G	G	G	G	G	G	F
Preplant or preemergence																			
Atrazine	G	F-G	F	P	P	P	P	F	G	F-G	G	G	G	G	G	G	G	G	F-G
Bladex	F-G	F-G	F-G	F-G	G	P	P	P	F	F-G	G	G	G	P-F	G	F-G	G	F-G	F-G
Bladex + atrazine[1]	F-G	F-G	F	F	F-G	P	P	P	F-G	F-G	G	G	G	G	G	F-G	G	F-G	F-G
Lasso, Dual	F-G	G	G	G	G	P-F	P-F	F-G	P	P	P	F	F-G	G	P-F	P	P-F	P	P
Lasso or Dual + atrazine or Bladex	F-G	G	G	G	G	P	P	F-G	F-G	F	G	G	G	G	G	F	G	F-G	F
Prowl[2] + atrazine[3] or + Bladex	F	G	G	G	G	F	F	P	F-G	F	G	G	G	G	G	F	G	F-G	F-G
Postemergence																			
Grass or broadleaf																			
Atrazine + oil	F-G	F-G	G	P	P	P	P	F	G	G	G	G	G	G	G	F-G	G	G	G
Bladex	F-G	G	G	F	F-G	P	P	F	F	F-G	G	G	G	P-F	G	F	G	F	F-G
Tandem + atrazine	F-G	G	G	F	P	F	F	F	G	G	G	G	G	G	G	G	G	G	G
Broadleaf only																			
Banvel	F-G	P	P	P	P	P	P	P	G	G	G	G	G	G	G	G	G	G	F
Basagran	G	P	P	P	P	P	P	F	P-F	G	G	F-P	P	P	F	F	G	G	F-G
Buctril	F-G	P	P	P	P	P	P	P	G	G	G	G	G	F	G	F	G	F-G	F
Laddok	G	P	P	P	P	P	P	F-G	G	G	G	G	G	G	G	G	G	G	G
2,4-D	F	P	P	P	P	P	P	P	G	G	F	G	F	G	G	G	F-P	G	F-G

[1] Bladex + atrazine premix = Extrazine II
[2] Do not use Prowl for preplant incorporation.
[3] Prowl + atrazine premix = Prozine

1989 Weed Control in Small Grains, Pastures, and Forages

Good weed control is necessary for maximum production of high-quality small grains, pastures, and forages in Illinois. When properly established, these crops can usually compete effectively with weeds so that the need for herbicide applications is minimized. Weeds, however, can sometimes become significant problems and warrant control. For example, wild garlic is considered the worst weed problem in wheat in southern Illinois. Because its life cycle is similar to that of winter wheat, wild garlic can establish itself with the wheat, grow to maturity, and produce large quantities of bulblets by wheat-harvest time. Economic considerations make it necessary to attempt some control of wild garlic in winter wheat.

In pastures, woody and herbaceous perennials can become troublesome. Annual grasses and broadleaf weeds such as chickweed and henbit may cause problems in hay crops. Through proper management, many of these weed problems can be controlled effectively.

Several herbicide labels carry the following groundwater warnings under either the environmental hazard or the groundwater advisory section. "X is a chemical that can travel (seep or leach) through soil and enter groundwater which may be used as drinking water. X has been found in groundwater as a result of its use as a herbicide. Users of this product are advised not to apply X where the soils are very permeable (that is, well-drained soils such as loamy sands) and the water table is close to the surface."

Small grains

Weed control is critical for maximum production of high-quality small grains. Often, weed problems can be dealt with before the crop is established. For example, many broadleaf weeds are controlled effectively in the late fall after corn or soybean harvest with 2,4-D, Banvel (dicamba), or Roundup (glyphosate).

Tillage helps control weeds. Although generally limited to preplant and postharvest operations, tillage can destroy many annual weeds and help suppress certain perennials. Good cultural practices such as proper seeding rate, optimum soil fertility, and timely planting help to establish an excellent stand and a crop that is better able to compete with weeds.

Winter annual grasses such as downy brome and cheat are very competitive in winter wheat. Illinois wheat producers are often limited to preplant tillage operations for control of these species as few herbicides have label clearances for annual grass control in winter wheat. If a severe infestation of downy brome or cheat exists, planting an alternative crop or spring crop may be best.

If annual broadleaf weeds later become a problem, a herbicide may be needed. Postemergence herbicides such as 2,4-D, MCPA, Banvel, and Buctril (bromoxynil) can provide good control of susceptible species (Table 79). Herbicides must be applied during certain growth stages of the crop to maintain crop safety and for optimum weed control. Refer to Figure 26 for a description of the growth stages of small grains.

Some perennial broadleaf weeds, however, may not be controlled satisfactorily at the low herbicide rates used in small grains; and higher rates are not advisable because they can cause serious injury to crops. To control perennial weeds, translocated herbicides such as 2,4-D, Banvel, or Roundup, in combination with tillage after corn or soybean harvest but before establishing small grains, may be the best approach.

Table 79. Effectiveness of Herbicides on Weeds in Small Grains

This table gives a general comparative rating. Under unfavorable conditions, some herbicides rated good or fair may give erratic or poor results. Under very favorable conditions, control may be better than indicated. Rate of herbicide used will also influence results. E = excellent, G = good, F = fair or variable, and P = poor.

Weed	Life cycle	Susceptibility to herbicide				
		2,4-D	MCPA	Banvel, 0.125 lb rate	Buctril, Brominal	Harmony
Dandelion	perennial	G	F	F	P	P-F
Horseweed (marestail)	annual	F	F	E	F	G
Lambsquarters, common	annual	E	E	E	G	G
Mustard, wild	annual	E	E	P	F	G
Nightshade, eastern black	annual	F	F	G	G	P
Pennycress, field	annual	E	E	P	F	G
Pigweed spp.	annual	E	E	E	F	G
Ragweed, common	annual	E	G	E	F	F
Ragweed, giant	annual	E	G	E	F	P
Shepherdspurse	annual	E	E	F	F	G
Smartweed	annual	P	F	G	G	G
Velvetleaf	annual	G	G	F	F	F-G
Wild buckwheat	annual	P	F	E	G	G
Wild garlic	perennial	F	F	P	P	G
Wild lettuce	annual	E	G	F	F	F

Wild garlic continues to be a major weed problem in winter wheat. Harmony (DPX-M6316), now registered for use in winter wheat, has given good control of wild garlic in University of Illinois research trials. When applied in the spring at 0.33 to 0.66 ounce of 75 DF per acre, Harmony effectively controls wild garlic aerial bulblets and some underground bulbs as well. Harmony also controls common lambsquarters, smartweed, and many species of mustard. See Tables 79 and 80 for additional information for Harmony.

A decision to use postemergence herbicides for broadleaf weed control in small grains should be based on several considerations:

1. *Nature of the weed problem.* Identify the species present and consider the severity of the infestation. Also note the size of the weeds. Weeds are usually best controlled while small.
2. *Stage of the crop.* Most herbicides are applied after full tiller until the boot stage. Do not apply herbicides from the boot stage to the hard-dough stage of most small grains. (See Figure 26 for a description of growth stages of small grains.)
3. *Presence of a legume underseeding.* Usually 2,4-D ester formulations and certain other herbicides listed in Table 80 should not be applied because they may damage the legume underseeding.
4. *Herbicide activity.* Determine crop tolerance and weed susceptibility to herbicides by referring to Tables 79 and 80. The lower rates in Table 80 are for more easily controlled weeds and the higher rates for the more difficult to control species. Tank-mixes may broaden the weed spectrum and thereby improve control; check the herbicide label for registered combinations.
5. *Economic justification.* Consider the cost of the treatment in terms of potential benefits such as the value of increased yield, improved quality of grain, and ease of harvesting the crop.

Table 80 outlines current suggestions for weed control options in wheat and oats, the two small grains most commonly grown in Illinois. Always consult the herbicide label for specific information about the use of a given product.

Grass pastures

Unless properly managed, broadleaf weeds can become a serious problem in grass pastures. They can compete directly with forage grasses and reduce the nutritional value and longevity of the pasture. Certain species, such as white snakeroot and poison hemlock, are also poisonous to livestock and may require special consideration.

Perennial weeds are probably of greatest concern. They can exist for many years, reproducing from both seed and underground parent rootstocks. Occasional mowing or grazing helps control certain annual weeds, but perennials can grow back from underground root reserves unless long-term control strategies are used.

Certain biennials can also flourish in grass pastures. The first year, they exist as a prostrate rosette, so that even close mowing does little to control their growth. The second year, biennials produce a seedstalk and a deep taproot. If these weeds are grazed or mowed at this stage, root reserves can sometimes enable the plant to grow again, thereby increasing its chance of surviving to maturity.

In general, the use of good cultural practices such as maintaining optimum soil fertility, rotational grazing, and periodic mowing can help keep grass pastures in good condition and more competitive with weeds. Where broadleaf weeds become troublesome, however,

Table 80. Weed Control in Small Grains

Herbicide	Broadcast rate/acre	Remarks	Restrictions
Oats and wheat			
2,4-D, 3.8 lb a.i. (amine)	½ to 1½ pt	Winter wheat more tolerant than oats. Apply in spring after full tiller but before boot stage. Do not treat in fall. Use lower rate of amine if underseeded with legume. Some legume damage may occur. May be used as preharvest treatment at 1 to 2 pints per acre during hard-dough stage.	Do not forage or graze within 2 weeks after treatment. Do not feed treated straw to livestock.
MCPA (amine)	¼ to 3 pt	Less likely than 2,4-D to damage oats and legume underseeding. Apply from 3-leaf stage to boot stage. Rate varies with crop and weed size and presence of legume underseeding.	Do not graze dairy animals on treated areas for 7 days after treatment.
Banvel, 4 lb a.i.	4 fl oz	Do not apply to small grains with legume underseeding. In fall-seeded wheat, apply before jointing stage. In spring-seeded oats, apply before oats exceed 5-leaf stage.	Do not graze or harvest for dairy feed before ensilage (milk) stage.
Buctril 2E	1 to 2 pt	Apply Buctril alone to fall-seeded small grains in the fall or spring, but before the boot stage. Weeds are best controlled before the 3- to 4-leaf stage. Buctril may be applied at 1 to 1½ pints per acre to small grains underseeded with alfalfa.	Do not graze treated fields for 30 days after application.
Wheat only			
2,4-D, 3.8 lb a.i. (ester)	½ to ¾ pt	Do not apply to wheat with legume underseeding. Apply in spring after full tiller but before boot stage. For preharvest treatment, apply 1 to 2 pints per acre during hard-dough stage. For control of wild garlic or wild onion, apply 1 to 2 pints in the spring when wheat is 4 to 8 inches high, after tillering but before jointing; these rates may injure the crop.	Do not forage or graze within 2 weeks after treatment. See current label for additional restrictions.
Harmony 75DF	⅓ to ⅔ oz	Apply to the crop after the 2-leaf stage, but before the boot stage. Wild garlic should be 6 to 12 inches tall, with 4 to 6 inches of new growth. Nonionic surfactant at 0.25% v/v or 1% v/v crop-oil concentrate should be included in the spray mixture unless liquid fertilizer is used as the carrier.	Do not plant to any crop other than wheat or barley within 30 days after application. Do not apply to cereals underseeded with legumes.

2,4-D or Banvel may be used. Roundup may also be used as a spot treatment, and Crossbow (2,4-D plus triclopyr) is labeled for control of broadleaf and woody plant species in permanent grass pastures. Certain formulations of Spike (tebuthiuron) may also be used in grass pastures for brush and woody plant control. (See Tables 81 and 82 for additional information.)

Proper identification of target weed species is important. As shown in Table 81, weeds vary in their susceptibility to herbicides. Timing of herbicide application may also affect the degree of weed control. Annuals and biennials are most easily controlled while young and relatively small. A fall or early spring treatment works best if biennials or winter annuals are the main weed problem. Summer annuals are most easily controlled in the spring or early summer. Apply translocated herbicides to control established perennials when the weeds are in the bud to bloom stage. Perennials are most susceptible at this reproductive phase because translocated herbicides can move downward with food reserves to the roots, potentially killing the entire plant.

For control of woody brush, apply 2,4-D, Banvel, or Crossbow when the plants are fully leafed and actively growing. Where regrowth occurs, a second treatment may be needed in the fall. During the dormant season, oil-soluble formulations of 2,4-D, Banvel or Crossbow may be used in fuel oil. Spike controls many woody perennials and should be applied to the soil in the spring. Spike requires rainfall to move it into the root zone of target species.

The weed control options in grass pastures are shown in Table 82. Be cautious with any pesticide and always consult the herbicide label for specific information about the use of a given product.

Forage legumes

Weed control is very important in managing forage legumes. Weeds can severely reduce the vigor of legume stands and thus reduce yield and forage quality. Good management begins with weed control practices that prevent weeds from becoming serious problems.

Establishment. To minimize problems, prepare the seedbed properly so that it is firm and weed-free. Select an appropriate legume variety. If you use high-quality seed and follow the recommendations for liming and fertility, the legume crop may crowd out many weeds and reduce the need for herbicides.

Table 81. Effectiveness of Herbicides on Weeds in Grass Pastures

This table gives a general comparative rating. Under unfavorable conditions, some herbicides rated good or fair may give erratic or poor results. Under very favorable conditions, control may be better than indicated. Rate of herbicide used will also influence results. E = excellent, G = good, F = fair or variable, P = poor, and N = none.

Weed	Life cycle	Susceptibility to herbicide			
		2,4-D	Banvel	Crossbow	Roundup
Burdock, common	biennial	E	E	E	G
Daisy, oxeye	perennial	F	E	E	G
Dandelion	perennial	E	E	E	F
Dock, curly	perennial	P-F	E	E	G
Goldenrod spp.	perennial	F	G	F	E
Horseweed (marestail)	annual	G	E	E	E
Ironweed	perennial	F	G	G	E
Milkweed, common	perennial	P	F	F	F
Multiflora rose	perennial	F	G	E	G
Nettle, stinging	perennial	G	G	G	G
Pennycress, field	annual	E	F	G	E
Plantain spp.	perennial	E	G	E	G
Poison hemlock	biennial	G	E	E	G
Ragweed, common	annual	E	E	E	E
Ragweed, giant	annual	E	E	E	E
Snakeroot, white	perennial	F	G	G	G
Sorrel, red	perennial	N	E	E	E
Sowthistle	perennial	F	G	E	G
Thistle, bull	biennial	E	E	E	E
Thistle, Canada	perennial	F	E	E	G
Thistle, musk	biennial	E	G	G	E
Water hemlock, spotted	perennial	G	E	E	G

In fields where companion crops such as oats are used to reduce weed competition, seed the small grain at half the rate for grain production to ensure that the legumes will establish with minimum stress. If the legume is seeded without a companion crop (direct seeded), the use of an appropriate herbicide is suggested.

Balan (benefin) and Eptam or Genep (EPTC) are registered for preplant incorporation for legumes that are not seeded with grass or small-grain companion crops. These herbicides will control most annual grasses and some broadleaf weeds. In fall plantings, the weeds controlled include winter annuals such as downy brome and cheat. In spring legume plantings, the summer annual weeds controlled include foxtails, pigweeds, lambsquarters, crabgrass, and fall panicum.

Eptam or Genep can help suppress johnsongrass and quackgrass seedlings, yellow nutsedge, and shattercane, in addition to many annual grasses and some broadleaf weeds. Neither one will effectively control mustards, smartweed, or established perennials. Balan, Eptam, and Genep, *must* be thoroughly incorporated soon after application to avoid herbicide loss. They should be applied shortly before the legume is seeded, so they remain effective as long as possible into the growing season.

Weeds that emerge during crop establishment should be evaluated for their potential to become problems. If they do not reduce the nutritional value of the forage or if they can be controlled by mowing, they should not be the primary target of a postemergence herbicide. For example, winter annual weeds do not compete vigorously with the crop after the first spring cutting. Unless they are unusually dense or production of weed seed becomes a concern, these weeds may not be a significant problem. Some weeds such as dandelions are palatable and may not need to be controlled if the overall legume stand is dense and healthy; but undesirable weeds must be controlled early to prevent their establishment.

Poast (sethoxydim) may be applied to seedling alfalfa for control of annual and some perennial grass weeds after weed emergence. Grasses are more easily controlled when small, and alfalfa is tolerant to Poast at all stages of growth. Butyrac or Butoxone (2,4-DB) controls many broadleaf weeds and may be applied postemergence in many seedling forage legumes. Buctril (bromoxynil) may now be used to control broadleaf weeds in seedling alfalfa. Apply Buctril while weeds are small. (See Table 84 for specific weed control ratings.)

Established legumes. The best weed control in established forage legumes is maintenance of a dense, healthy stand via proper management techniques. Chemical weed control in established forage legumes is often limited to late fall or early spring applications of herbicide. Sencor or Lexone (metribuzin), Sinbar (terbacil), and Velpar (hexazinone) are applied after the last cutting in the fall or in the early spring. These herbicides control many broadleaf weeds and some grasses, too. Kerb (pronamide) is used for grass control and is applied in the fall after the last cutting. 2,4-DB

Table 82. Broadleaf Weed Control in Grass Pastures

Herbicide	Rate/acre	Remarks	Restrictions
2,4-D, 3.8 lb a.i. (amine or low-volatile ester)	2 to 4 pt	Broadleaf weeds should be actively growing. Higher rates may be needed for less susceptible weeds and some perennials. Spray bull or musk thistles in the rosette stage (spring or fall) while they are actively growing. Spray perennials such as Canada thistle in the bud stage. Spray susceptible woody species in spring when leaves are fully expanded.	Do not graze dairy animals within 7 days after treatment. Do not apply to newly seeded areas or after heading begins. Do not apply to grass when it is in boot to milk stage.
Banvel, 4 lb a.i.	Annuals: ½ to 1½ pt Biennials: ½ to 3 pt Perennials: 1 to 2 pt (suppression) Perennials: 1 to 6 qt (control) Woody brush: 1 to 2 pt (suppression) Woody brush: 1 to 8 qt (control)	Use lower rates for susceptible annuals when they are small and actively growing and for susceptible biennials in the early rosette stage. Use higher rates for larger weeds, for less susceptible weeds, for established perennials in dense stands, and for certain woody brush species.	Refer to label for specific timing restrictions for lactating dairy animals. Remove meat animals from treated areas 30 days before slaughter.
Crossbow	Annuals: 1-2 qt Biennials and herbaceous perennials: 2 to 4 qt Woody perennials: 6 qt	Apply to foliage during warm weather when brush and broadleaf weeds are actively growing. When applying as a spot spray, thoroughly wet all foliage. Be cautious of vapor and particle drift, as Crossbow may injure susceptible crops growing nearby. See herbicide label for more specific rate recommendations.	Remove livestock from treated forage at least 3 days before slaughter during the year of treatment. Do not graze lactating dairy animals on treated areas for one year following treatment. Do not harvest grass for hay from treated areas for one year following treatment.
Roundup	2% solution (spot treatment)	Controls a variety of herbaceous and woody brush species such as multiflora rose, brambles, poison ivy, quackgrass. Spray foliage of target vegetation completely and uniformly, but not to point of runoff. Avoid contact with desirable nontarget vegetation. Consult label for recommended timing of application for maximum effectiveness on target species.	No more than $\frac{1}{10}$ of any acre should be treated at one time. Further applications may be made in the same area at 30-day intervals. Allow 14 days after application before grazing or harvesting forage.
Spike Brush Bullets	4-16 bullets/100 sq ft (See label rates for specific species.)	For control of brush and woody plants in rangeland and grass pastures. Requires sufficient rainfall to move herbicide into root zone. May kill or injure desirable legumes and grasses where contact is made. Injury is minimized by applying when grasses are dormant.	Do not apply on or near field crops or other desirable vegetation. Do not apply where soil movement is likely. Refer to label for additional restrictions.
Spike 20P	10-20 lb	Remarks and restrictions are the same as for Brush Bullets above.	

controls many broadleaf weeds in established alfalfa; 2,4-DB should be applied when the weeds are small and actively growing. Refer to Tables 83 and 84 for additional remarks and weed control suggestions.

Once grass weeds have emerged, they are particularly difficult to control in established alfalfa. Poast herbicide may be used in established alfalfa for control of annual and some perennial grasses. Optimum grass control is achieved if Poast is applied when grasses are small and before the weeds are mowed.

Table 83 outlines current suggestions for weed control options in legume forages. The degree of control will often vary with weed size, application rate, and environmental conditions. Be sure to select the correct herbicide for the specific weeds to be controlled (Table 84). Always consult the herbicide label for specific information about the use of a given product.

Acreage Conservation Reserve Program

The Acreage Conservation Reserve Program (ACR) continues to occupy substantial farmland in Illinois. Investing in good weed control on ACR land may help alleviate some problem weeds when rotating back to row crops. For example, perennial broadleaf weeds such as hemp dogbane and common milkweed may be controlled or suppressed under small-grain production or when a perennial grass or legume species is grown. In addition, mowing or alternative herbicide options may be available. Whether using tillage, mowing, herbicides, or combinations, the best approach is to remain flexible and utilize cost-effective methods that fit your weed problems and management system.

Clover, alfalfa, or other forage legumes may be one of the best options for ACR acres. The cover helps conserve soil, improves soil structure, and adds nitro-

Table 83. Weed Control in Forages

Herbicide	Legume	Time of application	Broadcast rate/acre	Remarks	Restrictions
PURE LEGUME FORAGES					
Seedling year					
Balan 1.5EC	Alfalfa, birdsfoot trefoil, red clover, ladino clover, alsike clover	Preplant incorporated	3 to 4 qt	Apply shortly before seeding. Do not use with any companion crop of small grains.	Do not use on soils high in organic matter.
Eptam 7E,10G or Genep 7E	Alfalfa, birdsfoot trefoil, lespedeza, clovers	Preplant incorporated	3½ to 4½ pt 30 lb	Apply shortly before seeding. Do not use with any companion crop of small grains.	Do not use on white Dutch clover.
Buctril 2E	Alfalfa only	Postemergence	1 to 1½ pt	Apply in the fall or spring to seedling alfalfa with at least 2 trifoliate leaves. Apply to weeds at or before the 4-leaf stage or 2 inches in height (whichever is first). May be tank-mixed with 2,4-DB for improved control of kochia and pigweed.	Do not apply when temperatures are likely to exceed 70°F at application or for the 3 days following application or when the crop is stressed. Do not add a surfactant or crop oil. Do not harvest or graze spring-treated alfalfa within 30 days and fall-treated alfalfa within 60 days following treatment (60 days if tank-mixed with 2,4-DB).
Butyrac 200 or Butoxone 2,4-DB	Alfalfa, birdsfoot trefoil, ladino clover, red clover, alsike clover, white clover	Postemergence	1 to 3 qt (amine) 3 to 4 pt (ester)	Use amine or ester formulation when weeds are less than 3 inches tall or less than 3 inches across if rosettes. Use higher rates for seedling smartweed or curly dock. Do not use on sweet clover.	Do not harvest or graze for 60 days following treatment.
Furloe 4EC	Alfalfa Certain clovers and birdsfoot trefoil	Postemergence	1 to 3 qt 1 to 2 qt	Apply after the 4-leaf stage in alfalfa. Used mainly for chickweed control.	Do not harvest or graze for 40 days.
Kerb 50W	Alfalfa, birdsfoot trefoil, crown vetch, clovers	Postemergence	1 to 3 lb	In fall-seeded legumes, apply after legumes have reached trifoliate stage. In spring-seeded legumes, apply next fall.	Do not graze or harvest for 120 days following application.
Poast 1.5E	Alfalfa only	Postemergence	¾ to 1½ pt	Alfalfa is tolerant of Poast at all stages of growth. Best grass control is achieved when applications are made prior to mowing. If tank-mixed with 2,4-DB, follow 2,4-DB harvest and grazing restrictions.	Do not apply Poast within 7 days of grazing, feeding, or harvesting undried forage, or within 20 days of harvesting dry hay. Do not apply more than a total of 5 pints of Poast per acre in one season. Apply by ground equipment only.
Established stands					
Butyrac 200 or Butoxone	Alfalfa only	Growing	1 to 3 qt (amine) 3 to 4 pt (ester)	Use amine or ester formulation. Spray when weeds are less than 3 inches tall or less than 3 inches wide if rosettes. Fall treatment of fall-emerged weeds may be better than spring treatment. Do not apply to sweet clover.	Do not harvest or graze for 30 days following application.
Furloe 4EC	Alfalfa Certain clovers and birdsfoot trefoil	Growing and dormant	1 to 3 qt 1 to 2 qt	Apply when moisture is sufficient to move herbicide into root zone. Used mainly for chickweed control.	Do not harvest or graze for 40 days following application.
Kerb 50W	Alfalfa, birdsfoot trefoil, crown vetch, clovers	Growing or dormant	1 to 3 lb	Apply in the fall after last cutting, when weather and soil temperatures are cool.	Do not harvest or graze for 120 days.

Table 83. Weed Control in Forages (continued)

Herbicide	Legume	Time of application	Broadcast rate/acre	Remarks	Restrictions
Sencor or Lexone	Alfalfa only	Dormant	¾ to 2 pt (4L) ½ to 1⅓ lb (75 DF) ¾ to 2 lb (50 WP)	Apply once in the fall or spring before new growth starts. Rate is based upon soil type and organic-matter content.	Do not use on sandy soils or soils with pH greater than 7.5. Do not graze or harvest for 28 days.
Sinbar 80W	Alfalfa only	Dormant	½ to 1½ lb	Apply once in the fall or spring before new growth starts. Use lower rates for coarser soils.	Do not use on sandy soils with less than 1% organic matter. Do not plant any crop for 2 years.
Velpar L	Alfalfa only	Dormant	1 to 3 qt	Apply in the fall or spring before new growth exceeds 2 inches in height. Can also be applied to stubble after hay crop removal but before regrowth exceeds 2 inches.	Do not plant any crop except corn within 2 years of treatment. Corn may be planted 12 months after treatment, provided deep tillage is used. Do not graze or harvest for 30 days.
Poast 1.5E	Alfalfa only	Postemergence	¾ to 1½ pt	Alfalfa is tolerant of Poast at all stages of growth. Best grass control is achieved when applications are made prior to mowing. If tank-mixed with 2,4-DB, follow 2,4-DB grazing and harvest restrictions.	Do not apply Poast within 7 days of grazing, feeding, or harvesting undried forage, or within 20 days of harvesting dry hay. Do not apply more than a total of 5 pints of Poast per acre in one season. Apply by ground equipment only.
Gramoxone Super	Alfalfa only	Dormant	2½ to 4 pt	Apply after last fall cutting or before sping growth is 1 inch tall. Weeds should be succulent and growing at the time of application. Weeds germinating after treatment will not be controlled. Add surfactant as label indicates.	A restricted-use herbicide. Do not apply if fall regrowth following the last fall cutting is more than 6 inches tall. Do not harvest or graze for 60 days.
Roundup	Alfalfa or clover	Growing	2% solution (spot treatment)	Apply to actively growing, susceptible weeds. Avoid contact with desirable, nontarget vegetation because damage may occur. Refer to label for recommended timing of application for maximum effectiveness on target species.	No more than 1/10 of any acre should be treated at one time. Further applications may be made in the same area at 30-day intervals. Do not graze or harvest for 14 days.
MIXED GRASS-LEGUME FORAGES Established stands					
Sencor or Lexone	Alfalfa-grass mixtures	Dormant	¾ to 1½ pt (4L) ½ to 1 lb (75 DF) ¾ to 1½ lb (50 WP)	Apply once in the fall or spring before new growth starts. Rate based on soil type and organic matter content. Higher rates may injure grass component.	Do not use on sandy soils or soils with pH greater than 7.5. Do not graze or harvest for 28 days.
Roundup	Alfalfa or clover-grass mixture	Growing	2% solution (spot treatment)	Apply to actively growing, susceptible weeds. Avoid contact with desirable, nontarget vegetation because damage may occur. Refer to label for recommended timing of application for maximum effectiveness on target species.	No more than 1/10 of any acre should be treated at one time. Further applications may be made in the same area at 30-day intervals. Do not graze or harvest for 14 days.

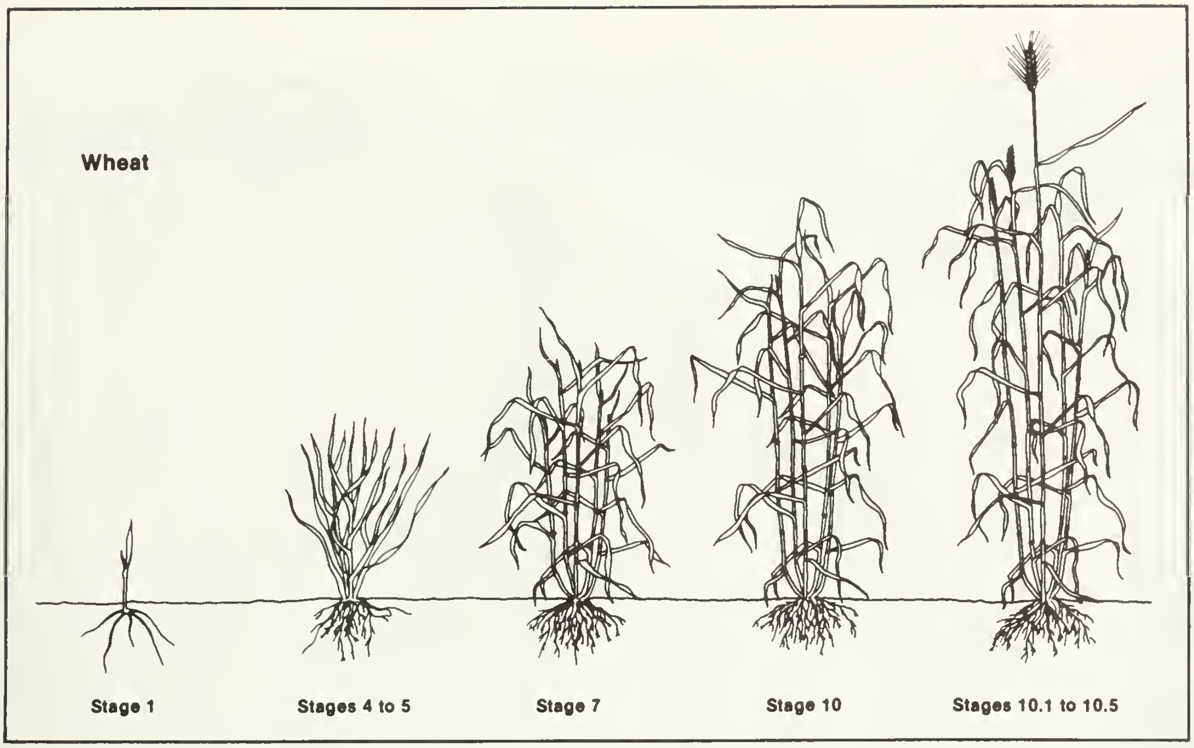


Figure 26. Growth stages of small grains.

Seedling

Stage 1. The coleoptile, a protective sheath that surrounds the shoot, emerges. The first leaf emerges through the coleoptile, and other leaves follow in succession from within the sheath of the previously emerging leaf.

Tillering

Stages 2 to 3. Tillers (shoots) emerge on opposite sides of the plant from buds in the axils of the first and second leaves. The next tillers may arise from the first shoot at a point above the first and second tillers or from the tillers themselves. This process is repeated until a plant has several shoots.

Stages 4 to 5. Leaf sheaths lengthen, giving the appearance of a stem. The true stems in both the main shoot and in the tillers are short and concealed within the leaf sheaths.

Jointing

Stage 6. The stems and leaf sheaths begin to elongate rapidly, and the first node (joint) of the stem is visible at the base of the shoot.

Stage 7. Second node (joint) of stem is visible. The next-to-last leaf is emerging from within the sheath of the previous leaf but is barely visible.

Stage 8. Last leaf, the "flag leaf," is visible but still rolled.

Stage 9: Preboot stage. Ligule of flag leaf is visible. The head begins to enlarge within the sheath.

Stage 10: Boot stage. Sheath of flag leaf is completely emerged and distended because of enlarging but not yet visible head.

Heading

Stages 10.1 to 10.5. Heads of the main stem usually emerge first, followed in turn by heads of tillers in order of their development. Heading continues until all heads are out of their sheaths. The uppermost internode continues to lengthen until the head is raised several inches above the uppermost leaf sheath.

Flowering

Stages 10.5.1 to 10.5.3. Flowering progresses in order of head emergence. Unpollinated flowers result in barren kernels.

Stage 10.5.4: Premilk stage. Flowering is complete. The inner fluid is abundant and clear in the developing kernels of the flowers pollinated first.

Ripening

Stage 11.1: Milk stage. Kernel fluid is milky white because of accumulating starch.

Stage 11.2: Dough stage. Kernel contents are soft and dry (doughy) as starch accumulation continues. The plant leaves and stems are yellow.

Stage 11.3. The kernel is hard, difficult to divide with the thumbnail.

Stage 11.4. Ripe for cutting. Kernel will fragment when crushed. The plant is dry and brittle.

Table 84. Effectiveness of Herbicides on Weeds in Legume and Legume-Grass[a] Forages

This table gives a general comparative rating. Under unfavorable conditions, some herbicides rated good or fair may give erratic or poor results. Under very favorable conditions, control may be better than indicated. Rate of herbicide used will also influence results. E = excellent, G = good, F = fair or variable, P = poor, and N = none.

	Balan	Genep, Eptam	Butyrac, Butox-one	Furloe	Kerb	Paraquat, Gramox-one	Sencor, Lexone[a]	Sinbar	Velpar	Roundup[a]	Poast	Buctril
Barnyardgrass	G	G	P	P	F	F	F	F	G	E	E	N
Chickweed, common	P	P	P	G	F	G	G	G	G	E	N	P
Crabgrass	G	G	P	P	F	F	F	G	G	E	E	N
Dandelion	P	P	F	P	P	F	G	P	G	G	N	P
Dock, curly	P	P	P	P	P	F	P	P	P	G	N	P
Downy brome	G	G	P	G	G	G	G	G	F	G	E	N
Fall panicum	G	G	P	P	P	F	F	P	P	E	E	N
Field pennycress	P	P	G	P	P	G	G	G	G	E	N	G
Foxtails	G	G	P	P	F	F	F	G	G	E	E	N
Henbit	P	G	P	P	F	G	G	G	F	G	N	F
Lambsquarters	G	G	F	P	P	F	G	G	G	E	N	G
Mustard, wild	P	P	E	P	P	G	G	G	G	E	N	F
Nightshade[b]	P	F	F	F	P	F	G	P	P	G	N	G
Orchardgrass	P	P	P	P	F	F	F	F	G	F	P-F	N
Pigweed	G	G	F	P	P	F	G	F	G	E	N	F
Quackgrass	P	F	P	P	G	P	F	F	F	G	F	N
Ragweed, common	P	P	G	P	P	F	G	F	F	E	N	G
Shepherdspurse	P	P	G	P	P	G	G	G	G	E	N	G
Smartweed	P	P	P	F	P	F	F	F	F	E	N	G
Yellow nutsedge	P	F	P	P	P	P	P	P	P	F	N	P

[a] Sencor, Lexone, and Roundup are labeled for use in mixed legume-grass forages. No other herbicides are cleared for this use.
[b] Control of different species may vary.

gen. Clover and alfalfa can be very economical, particularly if grown for at least two consecutive years. The use of a herbicide for legume establishment can allow a vigorous legume stand and alleviate the need for weed control measures later. If annual broadleaf weeds become a problem, applying 2,4-DB or mowing is another helpful option. Herbicides for use on forage legumes on ACR acres include those registered for commercial production fields and are listed in Table 83. In addition, Treflan (trifluralin) or Prowl (pendimethalin) may be used preplant incorporated to control annual grasses and some small-seeded broadleaf weeds. Some stand reduction may occur with Treflan or Prowl, but good weed control can compensate to allow for excellent establishment of the legume. Fusilade (fluazifop), Option (fenoxaprop), and Poast (sethoxidim) may be used for grass control postemergence on forage legumes on ACR land. With many of these products, haying and grazing are not allowed, therefore be sure to follow all restrictions imposed by the pesticide label.

Oats are commonly grown as a cover crop on set-aside acres. Oat seed is inexpensive and easy to obtain. If the Agricultural Stabilization and Conservation Service (ASCS) does not require clipping before seed maturity, oats can reseed themselves for fall cover. Wheat, rye, and barley are other small-grain cover crop possibilities.

Sowing clean oat, wheat, rye, or barley seed is the first step to minimizing weed problems. Small grains generally provide relatively good cover until they mature or the area is mowed; then weeds can soon proliferate. However, winter wheat or rye may be sown in the spring, and without the overwintering period (vernalization), little or no seed production occurs and a dense cover remains. Hoelon (diclofop) is one of the few options for control of grass weeds in wheat. Annual broadleaf weeds can be controlled by mowing and by the use of the herbicides listed in Table 80. Tillage prior to small-grain planting will help control established weeds.

Planting a small-grain/legume combination is another option for set-aside. Utilizing the small grain as a nurse or companion crop may help reduce weed pressure and alleviate the need for herbicides. If weeds become a problem, refer to Table 83 for more information in selecting the appropriate herbicide. In addition to those herbicides listed in Table 83, Buctril may also be used to control broadleaf weeds in seedling alfalfa-grass mixes on Conservation Reserve Program acres. Refer to current label rates and restrictions.

Sorghum-sudan grass can make a rapid, vigorous cover that also effectively suppresses many weeds. Although herbicides are rarely needed in sorghum-sudan grass stands, mowing and tillage may be difficult; and viable seed sometimes causes weed problems the next year.

Acreage Conservation Reserve land offers a unique opportunity for controlling problem weeds such as perennials and keeping other more common weeds in check. By managing ACR land this year, controlling weeds in future row crops will be less difficult and more profitable.

1.4 gy/mi =

Useful Facts and Figures

To convert column 1 into column 2, multiply by	Column 1	Column 2	To convert column 2 into column 1, multiply by
	Length		
0.621	kilometer, km	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
0.394	centimeter, cm	inch, in.	2.54
16.5	rod, rd	feet, ft	0.061
	Area		
0.386	kilometer^2, km^2	mile^2, mi^2	2.59
247.1	kilometer^2, km^2	acre, acre	0.004
2.471	hectare, ha	acre, acre	0.405
	Volume		
0.028	liter	bushel, bu	35.24
1.057	liter	quart (liquid), qt	0.946
0.333	teaspoon, tsp	tablespoon, tbsp	3
0.5	fluid ounce	tablespoon, tbsp	2
0.125	fluid ounce	cup	8
29.57	fluid ounce	milliliter, ml	0.034
2	pint	cup	0.5
16	pint	fluid ounce	0.063
	Mass		
1.102	ton (metric)	ton (English)	0.907
2.205	kilogram, kg	pound, lb	0.454
0.035	gram, g	ounce (avdp.), oz	28.35
	Yield		
0.446	ton (metric)/hectare	ton (English)/acre	2.24
0.891	kg/ha	lb/acre	1.12
0.891	quintal/hectare	hundredweight/acre	1.12
0.016	kg/ha-corn, sorghum, rye	bu/acre	62.723
0.015	kg/ha-soybean, wheat	bu/acre	67.249
	Temperature		
(9/5·C)+32	Celsius	Fahrenheit	5/9(F−32)

Plant Nutrition Conversion

P(phosphorus) × 2.29 = P_2O_5 $\qquad$ P_2O_5 × .44 = P

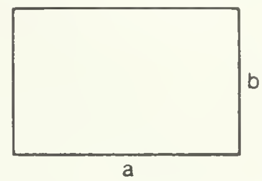
K(potassium) × 1.2 = K_2O $\qquad$ K_2O × .83 = K

ppm x 2 = lb/A (assumes that an acre plow depth of 6⅔ inches weighs 2 million pounds)

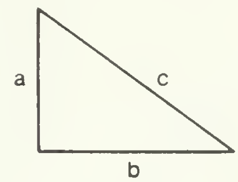
Useful Equations

$$\text{Speed (mph)} = \frac{\text{distance (ft)} \times 60}{\text{time (seconds)} \times 88}$$

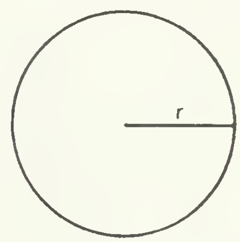
1 mph = 88′/min



Area = a × b



Area = ½ (a × b)



Area = πr^2
π = 3.1416

$$\text{lb/100 ft}^2 = \frac{\text{lb/acre}}{435.6}$$

$$\text{Example: 10 tons/acre} = \frac{20{,}000 \text{ lb}}{435.6} = 46 \text{ lb/100 ft}^2$$

$$\text{oz/100 ft}^2 = \frac{\text{lb/acre}}{435.6} \times 16$$

$$\text{Example: 100 lb/acre} = \frac{100}{435.6} \times 16 = 4 \text{ oz/100 ft}^2$$

$$\text{tsp/100 ft}^2 = \frac{\text{gal/acre}}{435.6} \times 192$$

$$\text{Example: 1 gal/acre} = \frac{1}{435.6} \times 192 = .44 \text{ tsp/100 ft}^2$$

Water weight = 8.345 lb/gal

Acre-inch water = 27,150 gal

405 ha / acre